Watershed

September 2021

Otter Tail River Watershed Total Maximum Daily Load Report

A quantification of the total maximum daily loads of *E. coli* bacteria, sediment, and phosphorus in the Otter Tail River Watershed's rivers and lakes needed to meet and maintain their ability to support aquatic life and aquatic recreation.

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Abbreviations

1W1P	One Watershed, One Plan
ARM	Agricultural Runoff Model
AU	Animal Unit
BMP	Best Management Practice
BWSR	Minnesota Board of Water and Soil Resources
CAFO	Concentrated Animal Feeding Operation
cfs	Cubic Feet Per Second
Chl-*a*	Chlorophyll-*a*
COLA	Coalition of Lakes Association
CRP	Conservation Reserve Program
CREP	Conservation Reserve Enhancement Program
CRNR	Central River Nutrient Region
CWA	Clean Water Act
CWLA	Clean Water Legacy Act
DO	Dissolved Oxygen
DNR	Minnesota Department of Natural Resources
E. coli	*Escherichia coli*
EDA	Environmental Data Access
EPA	U.S. Environmental Protection Agency
EQuIS	Environmental Quality Information System
GIS	Geographic Information Systems
HSPF	Hydrologic Simulation Program-Fortran
HUC-08	Eight-digit Hydrologic Unit Code
IBI	Index of Biotic Integrity
ITPHS	Imminent Threat to Public Health and Safety
JD	Judicial Ditch
kg/ha/yr	Kilograms Per Hectare Per Year
kg/km2/yr	Kilograms Per Square Kilometer Per Year
L/day	Liters Per Day
L/ft3	Liters Per Cubic Foot
LA	Load Allocation
LAP	Lake Agassiz Plain
LC	Loading Capacity
LDC	Load Duration Curve
lbs/acre/yr	Pound Per Acre Per Year
lbs/day	Pounds Per Day
lbs/yr	Pounds Per Year

LGU	Local Government Unit
LWMP	Local Water Management Plans
MAWQCP	Minnesota Agricultural Water Quality Certification Program
mg/day	Milligrams Per Day
mg/L	Milligrams Per Liter
mgd	Million Gallons Per Day
mL	Milliliter
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
MST	Microbial Source Tracking
N	Nitrogen
NCHF	North Central Hardwood Forests
NLCD	National Land Cover Database
NLF	Northern Lakes and Forests
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source(s)
NRCS	Natural Resource Conservation Service
NRS	Nutrient Reduction Strategy
NWR	National Wildlife Refuge
OTRW	Otter Tail River Watershed
P	Phosphorus
SDS	State Disposal System
SID	Stressor Identification
SSTS	Subsurface Sewage Treatment Systems
SWCD	Soil and Water Conservation District
SWPPP	Stormwater Pollution Prevention Plan
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
µg/L	Microgram Per Liter
WD	Watershed District
WID	Waterbody Identifier
WLA	Wasteload Allocation
WQBEL	Water Quality Based Effluent Limits
WRAPS	Watershed Restoration and Protection Strategy
WWTP	Wastewater Treatment Plant

Executive summary

Section 303(d) of the Clean Water Act (CWA) provides authority for completing Total Maximum Daily Loads (TMDLs) to achieve state water quality standards and/or designated uses. TMDLs are required to be developed for waters that do not support their designated uses and are determined to be impaired. The TMDL establishes the maximum amount of a pollutant a waterbody can receive on a daily basis and still meet water quality standards. The TMDL is divided into wasteload allocations (WLA) for point or permitted sources, load allocations (LA) for nonpoint sources (NPS) and natural background, and a margin of safety (MOS) to account for uncertainty in load estimates.

This report addresses impaired stream reaches and lakes in the Otter Tail River Watershed (OTRW) listed on Minnesota's 2020 303(d) Impaired Waters List[1] and requiring a TMDL. The OTRW eight-digit hydrologic unit code (HUC-08) is 09020103. This TMDL report specifically addresses 23 impairments in 10 stream reaches and 13 lakes in the watershed. Of these 23 impairments, 8 are caused by *Escherichia coli* (*E. coli*) bacteria and 2 are caused by total suspended solids (TSS) or turbidity in streams, and 13 are caused by excessive nutrients in lakes. Additionally, one stream impairment caused by poor fish bioassessments scores and one stream impairment caused by poor benthic macroinvertebrates bioassessments scores are proposed for recategorization upon completion of this TMDL report. The impairment caused by poor fish bioassessments scores is addressed by a previously approved TMDL report, and the impairment caused by poor benthic macroinvertebrates bioassessments scores is being addressed by an associated TSS TMDL in this report. Both are further described in **Section 1.2.** Addressing multiple impairments in one TMDL report is consistent with Minnesota's Water Quality Framework that seeks to develop watershed-wide protection and restoration strategies rather than focus on individual reach impairments.

This TMDL report does not address all of the impaired stream reaches and lakes in the OTRW that are listed on Minnesota's 2020 303(d) Impaired Waters List. The impaired stream reaches and lakes not included in this TMDL report are outlined in **Section 1.2** and **Appendix 3**.

The OTRW covers 1,249,541 acres (1,952 square miles) of land in west-central Minnesota. The majority of the watershed is within the counties of Otter Tail and Becker; however, smaller portions are located in Wilkin, Clearwater, Clay, and Mahnomen counties. The watershed contains over 1,300 lakes – more than any other Red River of the North Basin Watershed. Many of these lakes are greater than 1,000 acres in size and are considered high value recreational resources. The watershed also contains approximately 2,800 miles of streams and drainage channels which meander near and through many of the aforementioned lakes. Many of the stream miles within the watershed remain nonchannelized and unaltered.

This TMDL report used a variety of methods to evaluate current loading contributions by the various pollutant sources, as well as the allowable pollutant loading capacity (LC) of the impaired waterbodies. These methods include the use of the Hydrologic Simulation Program – FORTRAN (HSPF) model, the load duration curve (LDC) approach, and the BATHTUB lake eutrophication model. This document addresses

[1] https://www.pca.state.mn.us/water/minnesotas-impaired-waters-list

OTRW impairments identified as needing TMDLs in the applicable 10-year monitoring and assessment cycle.

A general strategy for implementation to address the impairments is included in this report. More details are included in the accompanying Watershed Restoration and Protection Strategy (WRAPS) report (MPCA 2020a). Reduction of NPS pollutants will be the focus of implementation efforts. NPS contributions are not regulated by permits, and some are not regulated at all. NPS contributions will generally need to be addressed on a voluntary basis. Permitted point sources are addressed through the Minnesota Pollution Control Agency's (MPCA) National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) Permit (from now on referred to as "Permit") programs. All WLAs apportioned in this TMDL report are consistent with currently permitted effluent limits where they apply. Therefore, no new or additional point source pollutant reductions are required at any permitted facilities with regulated effluent limits, such as wastewater treatment plants (WWTPs), as a result of this TMDL Report. However, this may not apply to permittees with no specifically permitted effluent limits.

1. Project overview

1.1 Purpose

Section 303(d) of the federal CWA requires that TMDLs be developed for waters that do not support their designated uses. These waters are referred to as "impaired" and are included in Minnesota's list of impaired waterbodies. The term "TMDL" refers to the maximum amount of a given pollutant a waterbody can receive on a daily basis and still achieve water quality standards. A TMDL study determines what is needed to attain and maintain water quality standards in waters that are not currently meeting them. A TMDL study identifies pollutant sources and allocates pollutant loads among those sources. The total of all allocations, including WLAs for permitted sources, LAs for nonpermitted sources (including natural background), and the MOS, which is implicitly or explicitly defined, cannot exceed the maximum allowable pollutant load.

The passage of Minnesota's Clean Water Legacy Act (CWLA) in 2006 provided a policy framework and resources to state and local governments to accelerate efforts to monitor, assess, and restore impaired waters and to protect unimpaired waters. The result has been a comprehensive "watershed approach" that integrates water resource management efforts, local governments, and stakeholders to develop watershed-scale TMDL reports, restoration and protection strategies, and plans for each of Minnesota's 80 major watersheds. The information gained and strategies developed in the watershed approach are presented in major watershed-scale WRAPS reports, which guide local water planning and implementation of restoration and protection of streams, lakes, and wetlands across the watershed, including those for which TMDL calculations are not made (BWSR 2014).

This report addresses impaired stream reaches and lakes in the OTRW that are listed on Minnesota's 2020 303(d) Impaired Waters List and require a TMDL. The OTRW's HUC-08 watershed code is 09020103. This TMDL report specifically addresses 23 impairments, 8 of which are caused by *E. coli* and 2 that are caused by TSS or turbidity in 10 stream reaches, along with 13 caused by excessive nutrients (phosphorus [P]) in lakes. Additionally, 2 stream impairments are proposed for recategorization upon completion of this TMDL report, further described below in **Section 1.2.**

The purpose of this TMDL report is to quantify the pollutant reductions needed to meet state water quality standards for *E. coli* and TSS in stream reaches and nutrients (P) in lakes. This TMDL report was developed in accordance with Section 303(d) of the CWA and provides WLAs and LAs for the watershed as appropriate.

1.2 Identification of waterbodies

This TMDL specifically addresses 23 impairments in 10 stream reaches and 13 lakes listed on Minnesota's 2020 303(d) Impaired Waters List for the OTRW. The lake impairments are caused by excessive nutrients and eutrophication indicators, and lead to the lakes not supporting aquatic recreation use. The stream impairments include eight caused by *E. coli*, resulting in the streams not supporting aquatic recreation use, and one caused by TSS and one caused by turbidity, resulting in the streams not supporting aquatic life use. The impairment caused by turbidity for the Otter Tail River, from Judicial Ditch (JD) 2 to Breckenridge Lake (Waterbody Identifier [WID] 09020103-504), was first listed on Minnesota's 2004 303(d) Impaired Waters List, but a TMDL has yet to be completed. Recent data indicate that TSS are high early in the season but meeting standards during the warmer months (MPCA 2019a). Therefore, the MPCA determined that the turbidity-caused impairment should continue to be included on the 2020 303(d) Impaired Waters List. As further discussed in **Section 2.4.1**, this TMDL report will address the turbidity-caused impairment as one caused by TSS.

The two impairments proposed for recategorization upon completion of this TMDL report were evaluated in the OTRW Stressor Identification (SID) Report for Streams (MPCA 2019b). For the impairment caused by poor fish bioassessments scores for the Otter Tail River, from Breckenridge Lake to the Bois de Sioux River (WID 09020103-502), the evidence suggests the impairment is attributed to insufficient physical habitat, a nonpollutant and further discussed below, and high suspended sediment. All other evaluated stressors were determined to be inconclusive or refuted. Therefore, MPCA has evaluated recategorizing this impairment as 4A on account of the completed Lower Otter Tail River Turbidity Total Maximum Daily Load Report (MPCA 2006). For the impairment caused by poor benthic macroinvertebrates bioassessments scores for the Otter Tail River, from JD 2 to Breckenridge Lake (WID 09020103-504), the evidence suggests the impairment is attributed to high suspended sediment. Again, all other evaluated stressors were determined to be inconclusive or refuted. Therefore, MPCA will propose recategorizing this impairment as 4A upon completion of the associated TSS TMDL for this stream reach. In both cases, it is expected that if sediment loading in the stream is reduced to meet the TMDLs, then the fish and macroinvertebrate bioassessments scores would improve as well. Both scenarios are further described in **Section 2.2**.

Table 1 summarizes the stream impairments and **Table 2** summarizes the lake impairments addressed in this TMDL report. The location of the impairments are shown in **Figure 4** and **Figure 3**, respectively.

Table 1. List of impaired streams in the OTRW addressed in this TMDL report.

WID	Waterbody Name	Pollutant/ Parameter	Designated Use Class[1]	Affected Use[2]	Listing Year
09020103-502	Otter Tail R, Breckenridge Lk to Bois de Sioux R	Fish Bioassessments[3]	1C, 2Bdg, 3	AQL	2020
09020103-504	Otter Tail R, JD 2 to Breckenridge Lk	Turbidity (to be addressed as TSS)	1C, 2Bdg, 3	AQL	2004
09020103-504	Otter Tail R, JD 2 to Breckenridge Lk	Macroinvertebrates Bioassessments[4]	1C, 2Bdg, 3	AQL	2020
09020103-526	Toad R, Little Toad Lk to T138 R38W S30, SW corner	*E. coli*	1B, 2Ag, 3	AQR	2020
09020103-543	Campbell Cr, Campbell Lk to Floyd Lk	Total Suspended Solids (TSS)	2Bg, 3	AQL	2020
09020103-574	Otter Tail R, Unnamed lk (56-0821-00) to Pelican R	*E. coli*	1C, 2Bdg, 3	AQR	2020
09020103-757	Unnamed cr, Unnamed cr to Dead Lk	*E. coli*	2Bg, 3	AQR	2020
09020103-761	Unnamed cr, CD 3 to Otter Tail R	*E. coli*	2Bg, 3	AQR	2020
09020103-764	JD 2, Unnamed ditch along 190th St to Otter Tail R	*E. coli*	2Bg, 3	AQR	2020
09020103-768	Pelican R, Reed Cr to Otter Tail R	*E. coli*	2Bg, 3	AQR	2020
09020103-770	Toad R, Unnamed cr to Pine Lk	*E. coli*	2Bg, 3	AQR	2020

WID	Waterbody Name	Pollutant/ Parameter	Designated Use Class[1]	Affected Use[2]	Listing Year
09020103-772	Pelican R, Highway 10 to Detroit Lk	*E. coli*	2Bg, 3	AQR	2020

[1]Designated use classifications and applicable water quality standards are further described in **Section 2**.
[2]AQL = aquatic life use; AQR = aquatic recreation use.
[3]The evidence suggests the impairment is attributed to insufficient physical habitat and high suspended sediment. This impairment is addressed by the completed *Lower Otter Tail River Turbidity Total Maximum Daily Load Report* (MPCA 2006).
[4]The evidence suggests the impairment is attributed to high suspended sediment. This impairment will be addressed by the associated TSS TMDL being completed for this stream reach.

Table 2. List of impaired lakes in the OTRW addressed in this TMDL report.

WID	Waterbody Name	Pollutant/Parameter	Designated Use Class[1]	Eco-region	Depth Class[2]	Affected Use[3]	Listing Year
03-0398-00	Wine	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2012
56-0210-00	Long	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0458-00	Crooked	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0502-00	West Spirit	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2008
56-0569-01	Norway (East Bay)	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0569-02	Norway (West Bay)	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0791-00	Unnamed	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0882-00	Devils	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0907-00	Grandrud	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0979-00	Johnson	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0982-00	Oscar	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-1014-00	Hovland	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-1525-00	Twin	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020

[1]Designated use classifications and applicable water quality standards are further described in **Section 2**.
[2]Ecoregion and depth classifications and applicable water quality standards are further described in **Section 2.2**.
[3]AQR = aquatic recreation use.

This TMDL report does not address 4 dissolved oxygen (DO)-, 1 benthic macroinvertebrates bioassessments-, and 4 fish bioassessments-caused impairments in 5 stream reaches, as well as 4 excessive nutrients- and 12 fish bioassessments-caused impairments in 16 lakes that do not already have completed TMDL studies. Of those, MPCA is proposing to defer the DO, benthic macroinvertebrate bioassessments, and fish bioassessments impairments for the Pelican River from Highway 10 to Detroit Lake (WID 09020103-772), due to a large scale wetland restoration project that is being planned for upstream of that reach. These three associated aquatic life use impairments may be expected to meet standards in the future as a result of the completed restoration project. Furthermore, the three remaining DO impairments in the OTRW are being deferred due to insufficient information to develop TMDLs at this time.

For the remaining aquatic life use impairments not addressed in this TMDL report, including DO, benthic macroinvertebrates bioassessments, and fish bioassessments, nonpollutant stressors such as insufficient flow, insufficient habitat, or loss of connectivity are not subject to load quantification and therefore do not require TMDLs. If a nonpollutant stressor is linked to a pollutant (e.g. habitat issues driven by TSS, or low DO caused by excess P) a TMDL is required. Pollutant and nonpollutant stressors of the OTRW benthic macroinvertebrates bioassessments and fish bioassessments impairments were evaluated in the OTRW SID Report for Streams (MPCA 2019b) and Lakes (DNR and MPCA 2019). In a number of cases in the OTRW, habitat, connectivity, and other nonpollutant stressors are not linked to pollutants. In some cases, impairments caused by stressors linked to conventional pollutants may require more data and information or further evaluation before a TMDL can be completed. For the two impairments proposed for recategorization and described above, TMDLs addressing conventional pollutant stressors (high suspended sediment) are already completed and approved or will be completed as part of this TMDL report. Note that all aquatic life use impairments – not just those with associated TMDLs – are further discussed in the OTRW SID Report for Streams (MPCA 2019b) and Lakes (DNR and MPCA 2019), and the OTRW WRAPS Report (MPCA 2020a).

Aquatic life use and aquatic recreation use impairments for streams and lakes not addressed in this TMDL report, including notes regarding why TMDLs were not completed for these impairments at this time, are further summarized in **Appendix 3**.

Finally, there is one turbidity-caused stream impairment and one nutrients-caused lake impairment that are not addressed in this TMDL report because they each have a TMDL study completed independent of and prior to this TMDL report. The Lower Otter Tail River Turbidity Total Maximum Daily Load Report (MPCA 2006) covers the turbidity-caused impairment in the Otter Tail River, from Breckenridge Lake to the Bois de Sioux River (WID 09020103-502). The St. Clair Lake Total Maximum Daily Load (TMDL) (MPCA 2016) covers the impairment caused by excessive nutrients in St. Clair Lake (WID 03-0382-00). Summary tables from these completed TMDLs are included as **Appendices** in this TMDL report.

1.3 Priority ranking

The MPCA's schedule for TMDL completions, as indicated on Minnesota's Section 303(d) Impaired Waters List, reflects Minnesota's priority ranking of these TMDLs. The MPCA has aligned TMDL priorities with the watershed approach. The schedule for TMDL completion corresponds to the WRAPS report completion schedule. The MPCA developed a state plan, Prioritization Plan for Minnesota 303(d) Listings to Total Maximum Daily Loads (MPCA 2015b), to meet the needs of the U.S. Environmental Protection Agency's (EPA's) national measure (WQ-27) under EPA's A Long-Term Vision for Assessment, Restoration and Protection under the CWA Section 303(d) Program (EPA 2013). As part of these efforts, the MPCA identified water quality impaired segments that will be addressed by TMDLs by 2022. The impaired waters addressed by this TMDL report are part of that MPCA prioritization plan to meet the EPA's national measure.

2. Applicable water quality standards and numeric water quality targets

The federal CWA requires states to designate beneficial uses for all waters and develop water quality standards to protect each use. Water quality standards consist of several parts:

- Beneficial uses—Identify how people, aquatic communities, and wildlife use our waters
- Numeric criteria—Amounts of specific pollutants allowed in a body of water that still protect it for the beneficial uses
- Narrative criteria—Statements of unacceptable conditions in and on the water
- Antidegradation protections—Extra protection for high-quality or unique waters and existing uses

Together, the beneficial uses, numeric and narrative criteria, and antidegradation protections provide the framework for achieving CWA goals. Minnesota's water quality standards are in Minn. R. chs. 7050 and 7052.

2.1 Beneficial uses

The beneficial uses for waters in Minnesota are grouped into one or more classes as defined in Minn. R. 7050.0140. The classes and associated beneficial uses are:

- Class 1 – domestic consumption
- Class 2 – aquatic life and recreation
- Class 3 – industrial consumption
- Class 4 – agriculture and wildlife
- Class 5 – aesthetic enjoyment and navigation
- Class 6 – other uses and protection of border waters
- Class 7 – limited resource value waters

The Class 2 aquatic life beneficial use includes a tiered aquatic life uses framework for rivers and streams. The framework contains three tiers—exceptional, general, and modified uses.

All surface waters are protected for multiple beneficial uses, and numeric and narrative water quality criteria are adopted into rule to protect each beneficial use. TMDLs are developed to protect the most sensitive use of a waterbody.

2.2 Narrative and Numeric criteria and state standards

Narrative and numeric water quality criteria for all uses are listed for four common categories of surface waters in Minn. R. 7050.0220. The four categories are:

- Cold water aquatic life and habitat, also protected for drinking water: Classes 1B; 2A, 2Ae, or 2Ag; 3; 4A and 4B; and 5

- Cool and warm water aquatic life and habitat, also protected for drinking water: Classes 1B or 1C; 2Bd, 2Bde, 2Bdg, or 2Bdm; 3; 4A and 4B; and 5
- Cool and warm water aquatic life and habitat and wetlands: Classes 2B, 2Be, 2Bg, 2Bm, or 2D; 3; 4A and 4B; and 5
- Limited resource value waters: Classes 3; 4A and 4B; 5; and 7

The narrative and numeric water quality criteria for the individual use classes are listed in Minn. R. 7050.0221 through 7050.0227. The procedures for evaluating the narrative criteria are presented in Minn. R. 7050.0150.

The MPCA assesses individual waterbodies for impairment for Class 2 uses—aquatic life and recreation. Class 2A waters are protected for the propagation and maintenance of a healthy community of cold water aquatic life and their habitats. Class 2B waters are protected for the propagation and maintenance of a healthy community of cool or warm water aquatic life and their habitats. Protection of aquatic life entails the maintenance of a healthy aquatic community as measured by fish and macroinvertebrate indices of biotic integrity (IBIs). Fish and invertebrate IBI scores are evaluated against criteria established for individual monitoring sites by waterbody type and use subclass (exceptional, general, and modified).

Additionally, the Minnesota narrative water quality standard for all Class 2 waters (Minn. R. 7050.0150, subp. 3) states that:

> *The aquatic habitat, which includes the waters of the state and stream bed, shall not be degraded in any material manner, there shall be no material increase in undesirable slime growths or aquatic plants, including algae, nor shall there be any significant increase in harmful pesticide or other residues in the waters, sediments, and aquatic flora and fauna; the normal fishery and lower aquatic biota upon which it is dependent and the use thereof shall not be seriously impaired or endangered, the species composition shall not be altered materially, and the propagation or migration of the fish and other biota normally present shall not be prevented or hindered by the discharge of any sewage, industrial waste, or other wastes to the waters.*

Unlike conventional pollutants such as TSS or nutrients, TMDLs for aquatic life IBI impairment listings cannot be directly calculated. However, a TMDL to address these impairments can be computed if a stressor causing the impairment can be quantified (e.g., high suspended sediment or TSS in streams and excessive nutrients/eutrophication in lakes). Pollutant and nonpollutant stressors of the OTRW benthic macroinvertebrates bioassessments and fish bioassessments impairments were evaluated in the OTRW SID Report for Streams (MPCA 2019b) and Lakes (DNR and MPCA 2019). The primary stressors investigated for biological impairments in streams, and summarized in Section 4.1 of the SID Report for Streams, include loss of longitudinal connectivity, flow regime instability, insufficient physical habitat, high suspended sediment, and low DO (MPCA 2019b). The primary stressors investigated for biological impairments in lakes, and summarized in Section 3.1 of the SID Report for Lakes, include eutrophication, physical habitat alteration, altered interspecies competition, (nonnative or invasive species), temperature regime changes, and decreased DO (DNR and MPCA 2019).

As discussed in **Section 1.2** and **Appendix 3**, one fish IBI impairment and one macroinvertebrate IBI impairment in two stream reaches are proposed for recategorization to 4A, as the SID Report for

Streams suggests that high suspended sediment is the only conventional pollutant supported as a stressor for each impairment, and TMDLs addressing the associated Turbidity impairments are already completed and approved or will be completed as part of this TMDL report. The remaining fish and macroinvertebrate IBI impairments in streams and lakes not addressed in this TMDL report will then be further evaluated for a future TMDL study or for proposed recategorization on a future Minnesota Impaired Waters List.

Both Class 2A and 2B waters are also protected for aquatic recreation activities including bathing and swimming, and the consumption of fish and other aquatic organisms. In streams, aquatic recreation is assessed by measuring the concentration of *E. coli* in the water, which is used as an indicator species of potential waterborne pathogens. To determine if a lake supports aquatic recreational activities, its trophic status is evaluated using total phosphorus (TP), Secchi depth, and chlorophyll-*a* (Chl-*a*) as indicators. The ecoregion standards for aquatic recreation protect lake users from nuisance algal bloom conditions fueled by elevated P concentrations that degrade recreational use potential.

2.3 Antidegradation policies and procedures

The purpose of the antidegradation provisions in Minn. R. ch. 7050.0250 through 7050.0335 is to achieve and maintain the highest possible quality in surface waters of the state. To accomplish this purpose:

- Existing uses and the level of water quality necessary to protect existing uses are maintained and protected.
- Degradation of high water quality is minimized and allowed only to the extent necessary to accommodate important economic or social development.
- Water quality necessary to preserve the exceptional characteristics of outstanding resource value waters is maintained and protected.
- Proposed activities with the potential for water quality impairments associated with thermal discharges are consistent with Section 316 of the CWA, United States Code, title 33, section 1326.

2.4 Otter Tail River Watershed water quality standards

2.4.1 Streams

Applicable water quality standards for impaired streams addressed in this TMDL report are shown in **Table 3**, while **Table 1** shows the specific impaired streams covered in this TMDL report.

Table 3. Surface water quality standards for stream reaches addressed in this TMDL report.

Parameter	Water Quality Standard	Units	Criteria	Period of Time Standard Applies
Escherichia coli (*E. coli*) (Class 2A, 2Bd, and 2B)	Not to exceed 126	org/100 mL	Monthly geometric mean	April 1 – October 31
	Not to exceed 1,260	org/100 mL	Upper 10th percentile per calendar month	
Total suspended solids (TSS)-Central Nutrient Region (Class 2B and 2Bd)	Not to exceed 30	mg/L	Upper 10th percentile during applicable period	April 1 – September 30

The Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment: 305(b) Report and 303(d) List (MPCA 2018) provides details regarding how waters are assessed for conformance to the water quality standards.

Escherichia coli

In 2008, Minnesota changed from a fecal coliform bacteria standard to an *E. coli* bacteria standard for aquatic recreation use impairments in streams. The bacteria standard change is supported by an EPA guidance document on bacteriological criteria (EPA 1986). Minn. R. 7050.0222 water quality standards for *E. coli* states:

> *Escherichia (E.) coli - Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.*

Although surface water quality standards are based on *E. coli*, WWTPs are permitted based on fecal coliform concentrations. A conversion factor of 126 *E. coli* organisms per 100 milliliter (org/100 mL) for every 200 fecal coliforms per 100 mL is assumed (MPCA 2009). The *E. coli* standard is based on the geometric mean of water quality observations. Geometric mean is used in place of arithmetic mean in order to describe the central tendency of the data, dampening the effect that very high or very low values have on arithmetic means.

Loading capacities for all *E. coli* TMDLs in this document were calculated using both applicable standards. However, since *E. coli* is assessed by month, LAs and estimated percent reductions for each impaired stream in this TMDL were calculated based on the monthly geometric mean standard.

Total Suspended Solids

In January of 2015, the EPA issued an approval of the adopted amendments to the State Water Quality Standards, replacing the historically used turbidity standard with TSS standards. TSS TMDLs may now replace turbidity TMDLs. Therefore, this TMDL report will treat the turbidity-caused impairment for the Otter Tail River, from JD 2 to Breckenridge Lake (WID 09020103-504), as an impairment caused by TSS. The Lower Otter Tail River Turbidity Total Maximum Daily Load Report (MPCA 2006) for the Otter Tail River, from Breckenridge Lake to the Bois de Sioux River (WID 09020103-502), will not be updated at this time.

TSS is a measurement of the weight of suspended mineral (e.g., soil particles) or organic (e.g., algae) sediment per volume of water (MPCA 2018). The Minnesota State TSS standards are based upon river nutrient regions, which are loosely based on ecoregions (MPCA 2019a). Most of the OTRW is located in the Central River Nutrient Region (CRNR), while the very northern headwaters portion of the OTRW is located in the North River Nutrient Region (NRNR) and the very southwestern portion of the OTRW is located in the South River Nutrient Region (SRNR). Although the most downstream reaches of the Otter Tail River, from Orwell Dam to the Bois de Sioux River, are located in the SRNR, the entire Otter Tail River is assigned to the CRNR since most of its watershed lies within the CRNR (MPCA 2019c). Additionally, Campbell Creek (WID 09020103-543) is also located within the CRNR. Therefore, the state TSS standard for the CRNR of 30 milligrams per liter (mg/L) (MPCA 2018) will be used for this TMDL report. According to Minn. R. 7050.0222, the state TSS standard may be exceeded for no more than 10% of the time during the applicable period of April 1 through September 30.

2.4.2 Lakes

Lake eutrophication standards are written to protect lakes as a function of their designated beneficial use. The lakes in the OTRW are considered Class 2B waters, which are protected for aquatic life and recreation. Minnesota categorizes its lake water quality standards by ecoregion and depth classification. All impaired lakes addressed in this TMDL report are in the North Central Hardwood Forest (NCHF) ecoregion and are in the shallow depth class (mean depth less than 15 feet). **Table 4** displays the standards for shallow lakes in the NCHF ecoregion, while **Table 2** shows the specific lakes addressed in this TMDL report.

Table 4. Surface water quality standards for lakes addressed in this TMDL report.

Ecoregion	Total Phosphorus	Chlorophyll-*a*	Secchi Disk Depth
North Central Hardwood Forests (NCHF)	Summer (June to September) average not to exceed:		
- Shallow Lakes[1]	60 µg/L[2]	20 µg/L	1.0 meter

[1]Shallow lakes defined as having a mean depth less than 15 feet.
[2]µg/L: micrograms per liter

The MPCA considers a lake impaired when the summer (June to September) average of TP and at least one of the response variables, Chl-*a* or Secchi disk depth, fail to demonstrate compliance with the standards (MPCA 2018). In addition to meeting TP standards, Chl-*a* and Secchi disk depth standards must also be met for the resource to be considered “fully supporting” of its designated use. In developing the lake nutrient standards for Minnesota lakes (Minn. R. ch. 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state’s ecoregions (MPCA 2005). Clear relationships were established between the causal factor (TP) and the response variables, Chl-*a* and Secchi disk transparency. Based on these relationships it is expected that by meeting the P target in each lake, the Chl-*a* and Secchi standards will likewise be met.

3. Watershed and waterbody characterization

The OTRW drains an area of approximately 1,952 square miles (1,249,541 acres) in west-central Minnesota. The majority of the watershed is within the counties of Otter Tail and Becker; however, smaller portions are located in Wilkin, Clearwater, Clay, and Mahnomen counties. The watershed contains over 1,300 lakes – more than any other Red River Basin Watershed. Many of these lakes are greater than 1,000 acres in size and are considered high value recreational resources. The watershed also contains approximately 2,800 miles of streams and drainage channels which meander near and through the aforementioned lakes. Many of the stream miles within the watershed remain nonchannelized and unaltered.

The northern tip of the watershed is located in the White Earth Reservation (see **Figure 1**). While there are three OTRW lakes within the Reservation that were assessed and identified by MPCA as having impaired aquatic recreation, none of those will be addressed in this TMDL report. This assessment list was prepared under authority in state law to determine whether waters within the state are impaired. For purposes of the 303(d) list, these assessments are only advisory to EPA because these waterbodies are located wholly within a federally recognized Indian reservation, and EPA has stated that it does not approve the state's impaired waters listings for waters that are within the boundaries of an Indian reservation. Note that the MPCA includes parcels held in trust (tribal trust lands) in the definition of Indian reservation. Consultation requests for this project were sent to the White Earth Band of Ojibwe, as well as other interested Tribal Organizations, but no input from the Tribal Organizations was received. The White Earth Nation and other Tribal Organizations will continue to be included in communications about the OTRW WRAPS and TMDL project.

In addition to the three impaired lakes mentioned above, the White Earth Reservation includes a portion of the drainage area for one OTRW impaired stream (see **Figure 6**). Even though a small portion of the drainage area of one impaired stream reach (WID 09020103-574) addressed in this TMDL report is located in the White Earth Reservation, this TMDL report and calculated load reductions do not apply to any land and/or waters in the White Earth Reservation.

The headwaters of the Otter Tail River lie within the far northeastern portion of the OTRW, where approximately 68 square miles is located within the Tamarac National Wildlife Refuge (NWR). The Otter Tail River originates at the outlet of Elbow Lake as a small low gradient stream with a wetland riparian zone. The river flows south for approximately seven miles and consists of a series of short connecting channels between Little Bemidji Lake, Many Point Lake, and Round Lake. Dams are present at the outlet of each lake. After exiting Round Lake, the river winds south and west for approximately 12 miles, passing through several large wetland complexes and two dams before entering Height of Land Lake. The river flows through a dam at the outlet of Height of Land Lake and flows west through another large wetland area (and dam) before turning toward the south. The river exits the Northern Lakes and Forest (NLF) Ecoregion, an area characterized by nutrient poor soils and morainal hills, and enters the NCHF Ecoregion.

The NCHF ecoregion contains varying topography and more productive soils. Row crop and pastureland become more prevalent as the river progresses south through this region. Most of this region of the watershed also lies within a glacial outwash plain containing thick deposits of sand and other fine sediments. As a result, crop irrigation is prevalent throughout the central region of the watershed. The river winds south for approximately 35 miles, passing through an impoundment (Albertson Lake) near the town of Frazee, before turning southeast and entering Little Pine Lake and Big Pine Lake. Dams are present on the outlets of Albertson Lake, Little Pine Lake, and Big Pine Lake.

The Toad River, a major tributary within the OTRW, drains 111 square miles of land into Big Pine Lake. The Toad River originates from Little Toad Lake, located in the far northeastern region of the watershed, and flows primarily toward the south for 21 miles before emptying into Big Pine Lake. The headwaters of the Toad River are located within the heavily forested NLF Ecoregion. Land use within the remaining portion of the subwatershed consists primarily of pasture and hay, with smaller patches of forest and row crop. The majority of the Toad River maintains a low gradient character and is bordered by a wetland riparian zone. Portions of the Toad River have been straightened and even redirected from the original flow path. Several small tributary streams, including the cold-water stream Deadhorse Creek, drain the land along the eastern edge of the OTRW into the Toad River.

After exiting Big Pine Lake, the Otter Tail River flows south for approximately 15 miles, passing through Rush Lake and entering Otter Tail Lake. Dams are present at the outlet of both lakes. Otter Tail Lake also receives water from the Dead River (through Walker Lake), which drains 150 square miles of land within the south-central region of the watershed. The Dead River drainage area features numerous lakes and small wetlands (> 150 waterbodies). Forested land and agricultural land are distributed throughout this drainage. After exiting Otter Tail Lake, the Otter Tail River Continues winding west for approximately 17 miles. The river passes through numerous small lakes and two impoundments before turning south and entering another small impoundment. At this point of diversion, a portion of the water from the river is routed through a channel for cooling purposes at a power plant. This diversion channel later rejoins the river within the community of Fergus Falls. From the point of diversion, the river winds east, south, and then west before entering the community of Fergus Falls. The river passes through two impoundments located within the community and continues west before being joined by the Pelican River.

The Pelican River, the largest tributary of the Otter Tail River, drains 492 square miles of land along the western edge of the OTRW. Much of the eastern half of the Pelican River Watershed is forested, while the western half is a mixture of hay/pastureland and row crop. Numerous lakes are present within the upper Pelican River drainage. The Pelican River originates as a small-channelized stream from a wetland area located north of Floyd Lake, approximately six miles north of Detroit Lakes. The river flows south for 10 miles and empties into Detroit Lake. Almost the entire reach of the river from its headwaters to Detroit Lake has been altered (straightened). After exiting Detroit Lake, the Pelican River consists of short connecting channels between numerous lakes of various sizes. Dams are present at the outlet of most of these lakes. The river exits Prairie Lake, the last large lake within the flow path, and enters an impoundment located within the community of Pelican Rapids. With the exception of one impoundment located near Elizabeth, the remaining 42 miles of the Pelican River are continuous. Throughout its course, most of the Pelican River is low gradient and bordered by a wetland riparian zone.

After the confluence of the Pelican River, the Otter Tail River enters the Lake Agassiz Plain (LAP) ecoregion– a flat area dominated by row crop agriculture. The flat topography and poor natural drainage within this ecoregion necessitated the creation of extensive drainage systems throughout this portion of the watershed to aid development and agriculture. The soils of the LAP consist of fine lake sediments; as a result, turbidity increases as the river progresses west. The river turns south and flows into two reservoirs – Dayton Hallow and Orwell Lake. Orwell Lake is a large reservoir that was constructed to store water for irrigation, flood control, and drinking water purposes. Flows are regulated on the remaining 29 miles of the Otter Tail River due to operation of the Orwell Dam.

After Orwell Lake, the river winds west for approximately 8 miles and is joined by JD 2. JD 2 flows from north to south and drains 68 square miles of agricultural land. An extensive network of ditches drains the southwestern portion of the OTRW. Many of these ditches flow from east to west before converging with larger ditches that drain toward the south or southwest. A long segment of the lower Otter Tail River was also straightened to increase drainage and reduce flooding. This segment begins approximately six miles west of the JD 2 confluence and extends almost to Breckenridge Lake. The river returns to a natural channel and continues meandering west for seven miles before entering the community of Breckenridge. The Otter Tail River passes through the community and joins the Bois de Sioux River to form the Red River of the North (MPCA 2019a).

Pre-settlement vegetation in the watershed is shown in **Figure 2**. Historically, most of the land within the OTRW was forested. Hardwood forests and oak savannah covered much of the central portion of the watershed, while large tracts of pine were present in the far northern regions. Tallgrass prairie was interspersed with forested land along the western edge of the watershed and was especially prominent in the southwestern portion of the watershed (within the LAP ecoregion).

According to the 2011 National Land Cover Database (NLCD), wetlands account for 6.7% of the land within the watershed (**Figure 7**). Most of the tallgrass prairie and areas of oak savannah have also been cleared and converted to agricultural land. Approximately 27.1% of the land within the watershed is used for row crop production and another 17.8% is used for pasture and hay. The Natural Resource Conservation Service (NRCS) estimates 2,241 farms are located within the watershed and approximately 51% are less than 180 acres in size (MPCA 2019a). Forests cover 27.9% of the land within the watershed. The most contiguous tracts of forest lie within the relatively undeveloped northeastern region of the watershed where the Otter Tail River begins. The Tamarac NWR and White Earth Reservation are also in this region of the watershed. Developed land accounts for 5.7% of the watershed. Most development is concentrated around larger communities such as Fergus Falls, Detroit Lakes, Pelican Rapids, and Perham; however, development is also prevalent around many of the larger lakes within the watershed. The numerous lakes (open water) scattered throughout the watershed account for 14.8% of the watershed area.

More information on the watershed characteristics of the OTRW can be found in the Watershed Context Report-Otter Tail River (DNR 2017) and the Otter Tail River Watershed Monitoring and Assessment Report (MPCA 2019a).

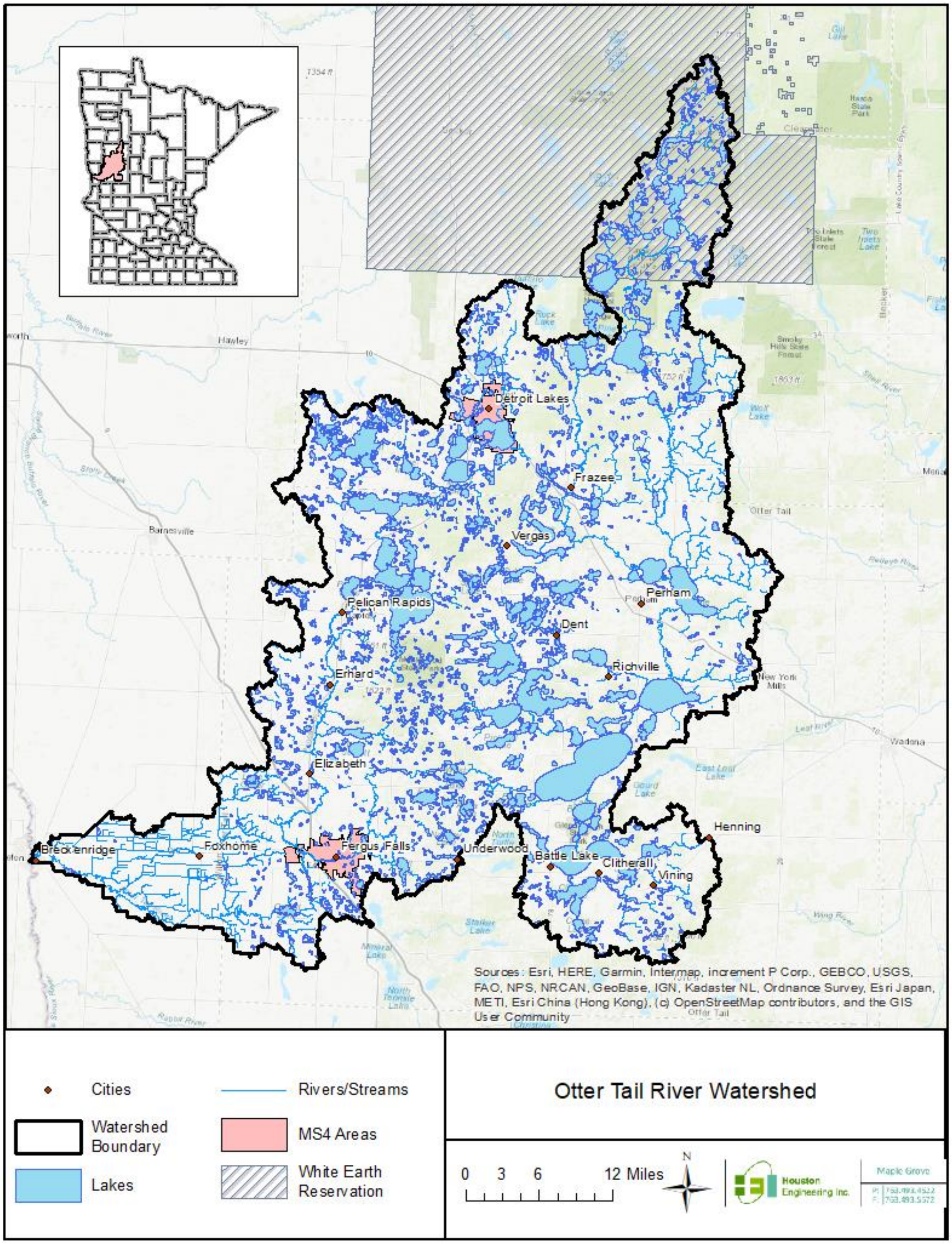

Figure 1. The Otter Tail River Watershed (OTRW).

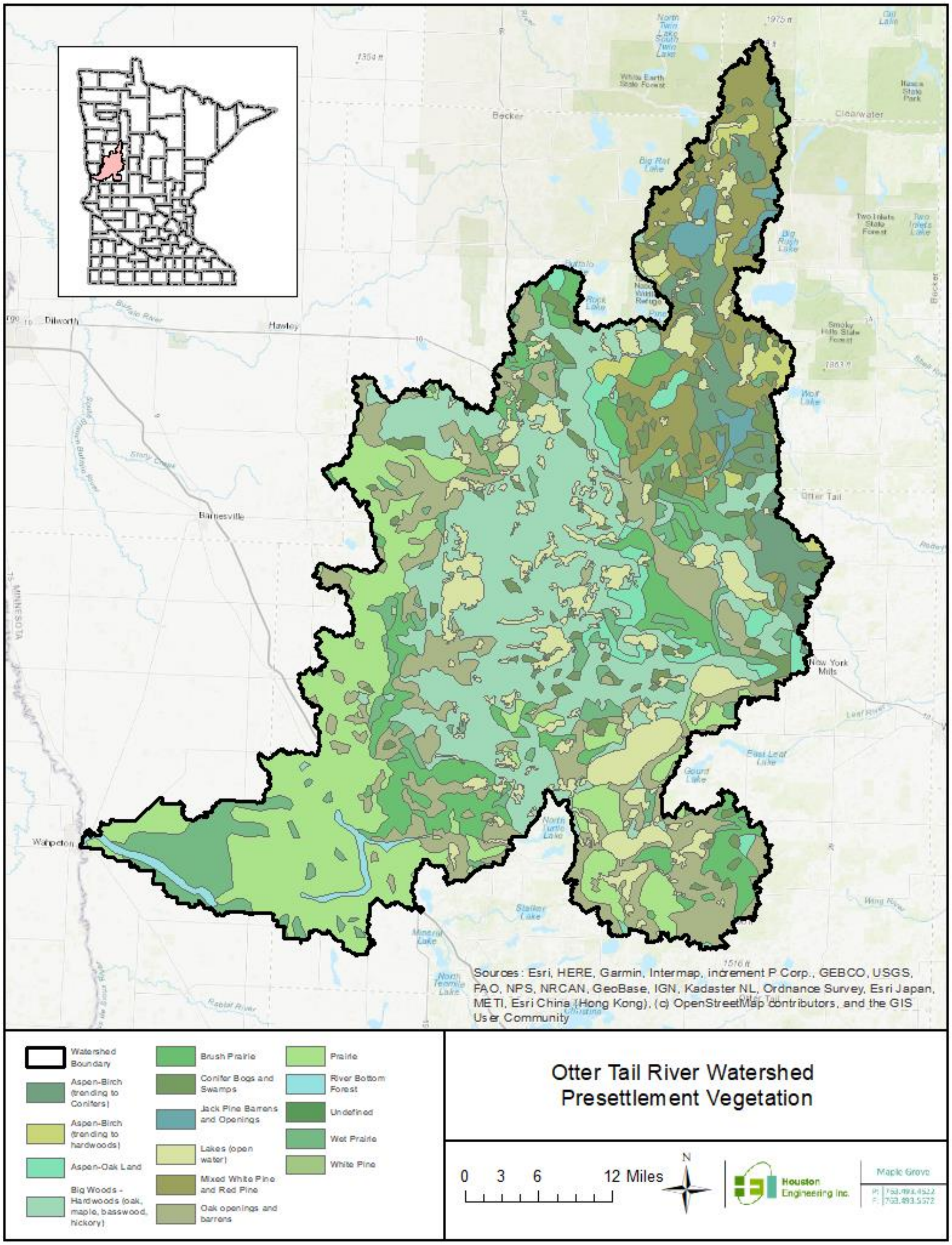

Figure 2. Pre-settlement vegetation in the OTRW.

3.1 Lakes

Thirteen excessive nutrients impairments in lakes in the OTRW are addressed in this TMDL report. All lakes addressed in this TMDL report are assessed as shallow lakes, i.e. having a mean depth less than 15 feet, and are located in the NCHF ecoregion. The surface area, average and maximum depths, lakeshed area, and lakeshed area to surface area ratios are provided in **Table 5**. The locations of the impaired lakes are shown in **Figure 3**. The drainage areas for the impaired lakes is shown in **Figure 5**.

Table 5. Approximate drainage areas of impaired lakes addressed in this TMDL report.

WID	Lake Name	Surface Area [acres]	Average Depth [feet]	Max Depth	Lakeshed Area - Total Drainage [acres]	Lakeshed Area: Surface Area Ratio
03-0398-00	Wine	31.2	3	5.5	169	5.42
56-0210-00	Long	1,092	5	16	2,787	2.55
56-0458-00	Crooked	132	7	20	1,203	9.12
56-0502-00	West Spirit	261	6	18	556	2.13
56-0569-01	Norway (East Bay)	314	6	19	996	3.17
56-0569-02	Norway (West Bay)	93.0	6	19	2,222	23.89
56-0791-00	Unnamed	140	4	10.5	761	5.44
56-0882-00	Devils	308	6	18	1,632	5.30
56-0907-00	Grandrud	113	7	21	553	4.89
56-0979-00	Johnson	154	2	3	1,186	7.7
56-0982-00	Oscar	337	3	6	9,421	28.0
56-1014-00	Hovland	181	7	20	2,071	11.45
56-1525-00	Twin	181	4	10	802	4.44

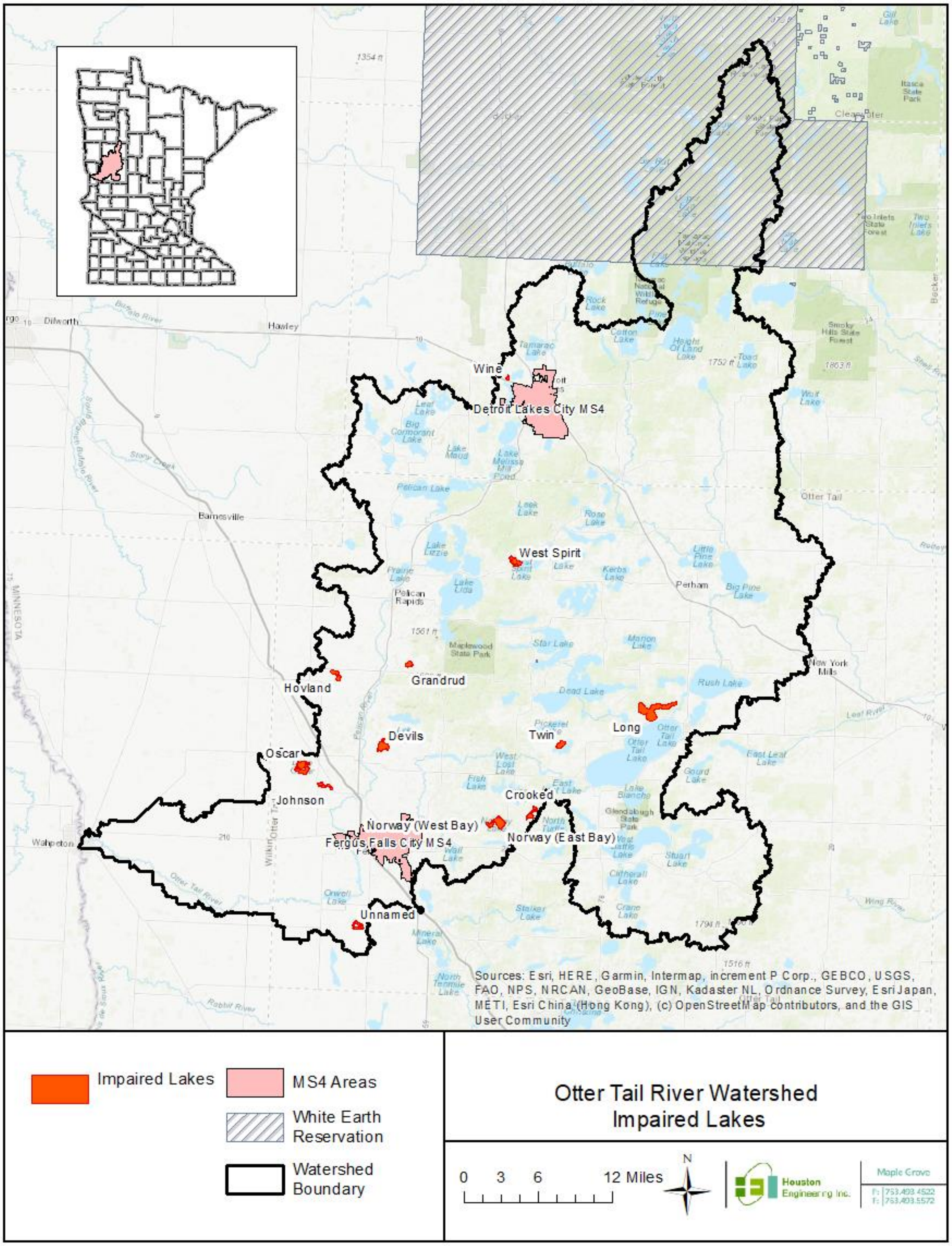

Figure 3. Impaired lakes in the OTRW addressed in this TMDL report.

3.2 Streams

Ten impaired stream reaches in the OTRW are addressed in this TMDL report, the drainage areas of which cover most of the watershed (see **Figure 6**). The impaired stream reaches are shown in **Figure 4** and their reach lengths and drainage areas are provided in **Table 6**.

The drainage areas for the impaired stream reaches are shown in **Figure 6.** Many of these drainage areas overlap. In those cases, the upstream, overlapping drainage area is shown over any downstream, overlapped drainage area. For example, the drainage area for the Otter Tail River (WID 09020103-504) covers most of the watershed and is overlapped by the drainage areas for all other impaired stream reaches other than Unnamed Creek (WID – 761). Individual drainage area maps for the impaired stream reaches are provided in **Appendix 4**, provided, generally, from upstream to downstream.

The drainage areas for the impaired stream reaches include both non-contributing and contributing areas. According to the Otter Tail River Basin HSPF model, further described in **Section 4.1.2.1**, significant portions of the OTRW are internally drained and therefore do not contribute to OTRW stream flows. These non-contributing areas were identified as having the natural storage capacity to hold all surface runoff from a 100-year, 10-day storm event. However, these areas are identified as contributors to nearby lakes and groundwater via subsurface pathways and aquifer connections (Tetra Tech 2017). The non-contributing areas are shown in **Figure 6** and **Appendix 4**.

Table 6. Approximate drainage areas of impaired streams addressed in this TMDL report.

WID	Stream/Reach Name	Reach Length [miles]	Total Drainage Area		Total Non-contributing Area	Total Contributing Area
			[acres]	[sq. mi.]	[acres]	[acres]
09020103-504	Otter Tail R, JD 2 to Breckenridge Lk	18.66	1,196,672	1,870	432,362	764,310
09020103-526	Toad R, Little Toad Lk to T138 R38W S30, SW corner	10.59	52,803	82.5	4,176	48,627
09020103-543	Campbell Cr, Campbell Lk to Floyd Lk	3.8	8,234	12.9	1,417	6,816
09020103-574	Otter Tail R, Unnamed lk (56-0821-00) to Pelican R	2.75	766,132	1,197	269,863	496,269
09020103-757	Unnamed cr, Unnamed cr to Dead Lk	2.76	7,360	11.5	951	6,409
09020103-761	Unnamed cr, CD 3 to Otter Tail R	2.76	22,163	34.6	0	22,163
09020103-764	JD 2, Unnamed ditch along 190th St to Otter Tail R	2.09	42,684	66.7	14,499	28,185
09020103-768	Pelican R, Reed Cr to Otter Tail R	22.87	316,404	494	136,936	179,468
09020103-770	Toad R, Unnamed cr to Pine Lk	4.09	71,777	112	5,988	65,790
09020103-772	Pelican R, Highway 10 to Detroit Lk	0.98	35,896	56.1	9,537	26,359

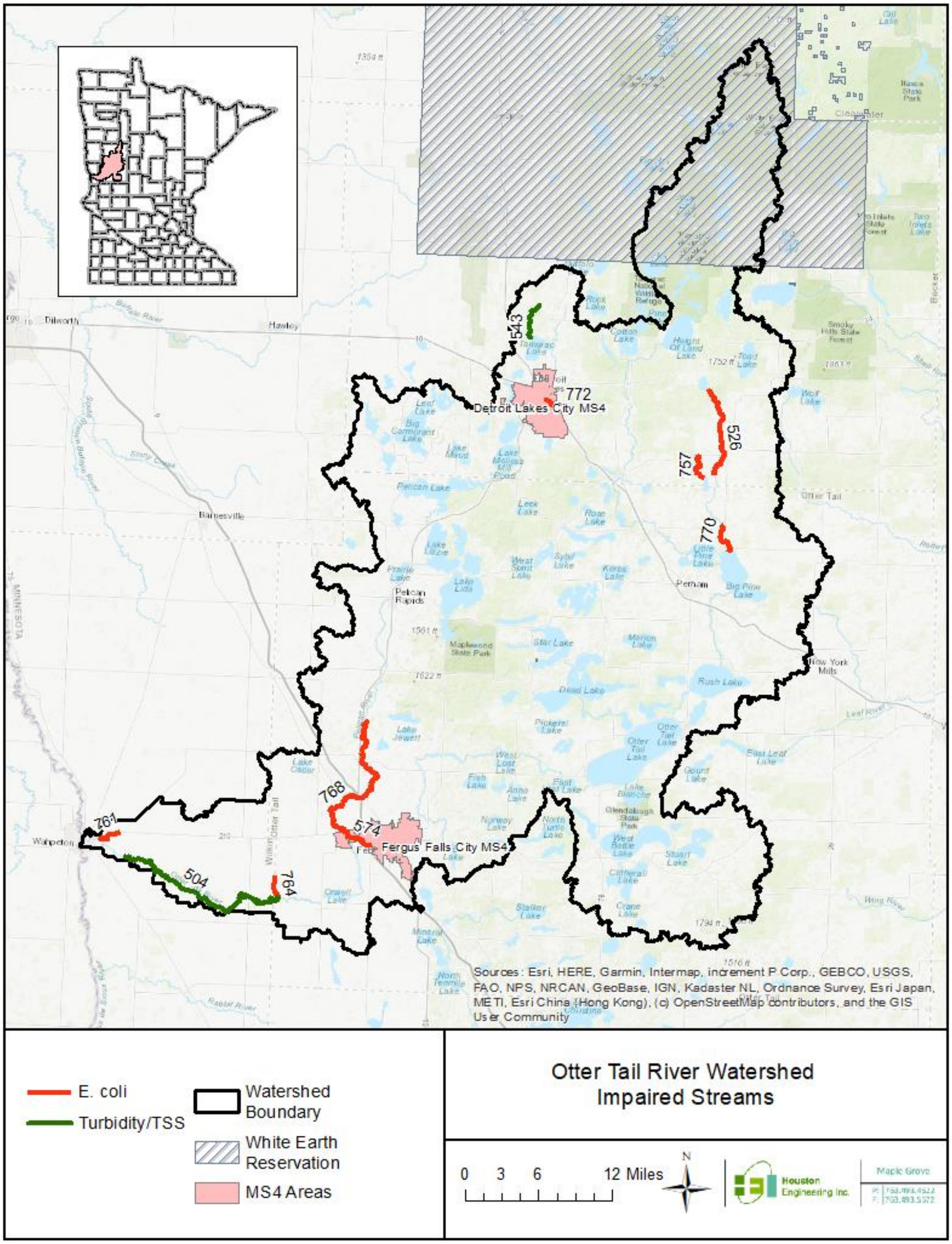

Figure 4. Impaired streams in the OTRW addressed in this TMDL report.

3.3 Subwatersheds

The drainage areas (subwatersheds) for each impaired lake are provided in **Figure 5.**

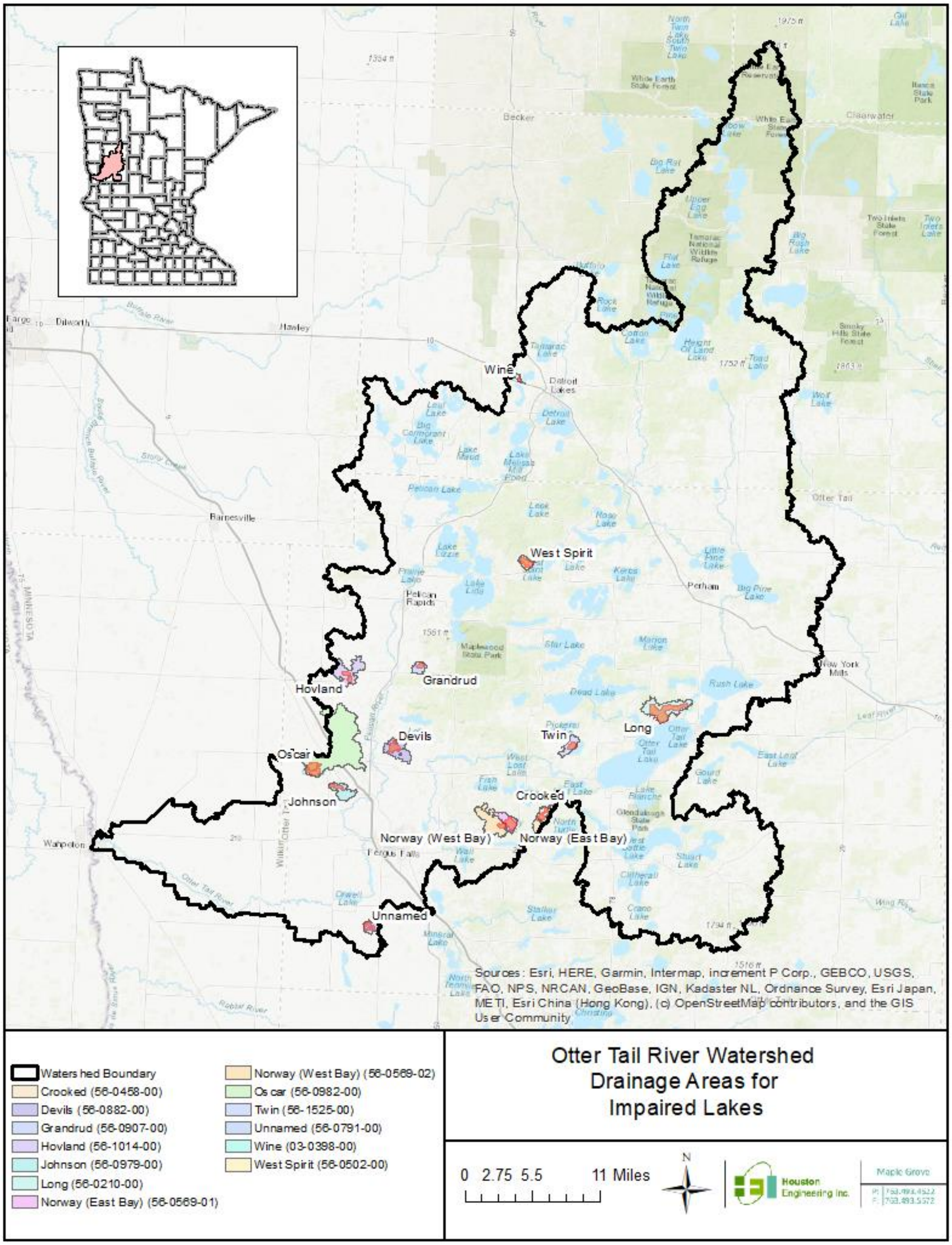

Figure 5. Drainage areas of impaired lakes in the OTRW addressed in this TMDL report.

The drainage areas (subwatersheds) for each impaired stream are provided in **Figure 6** and **Appendix 4**.

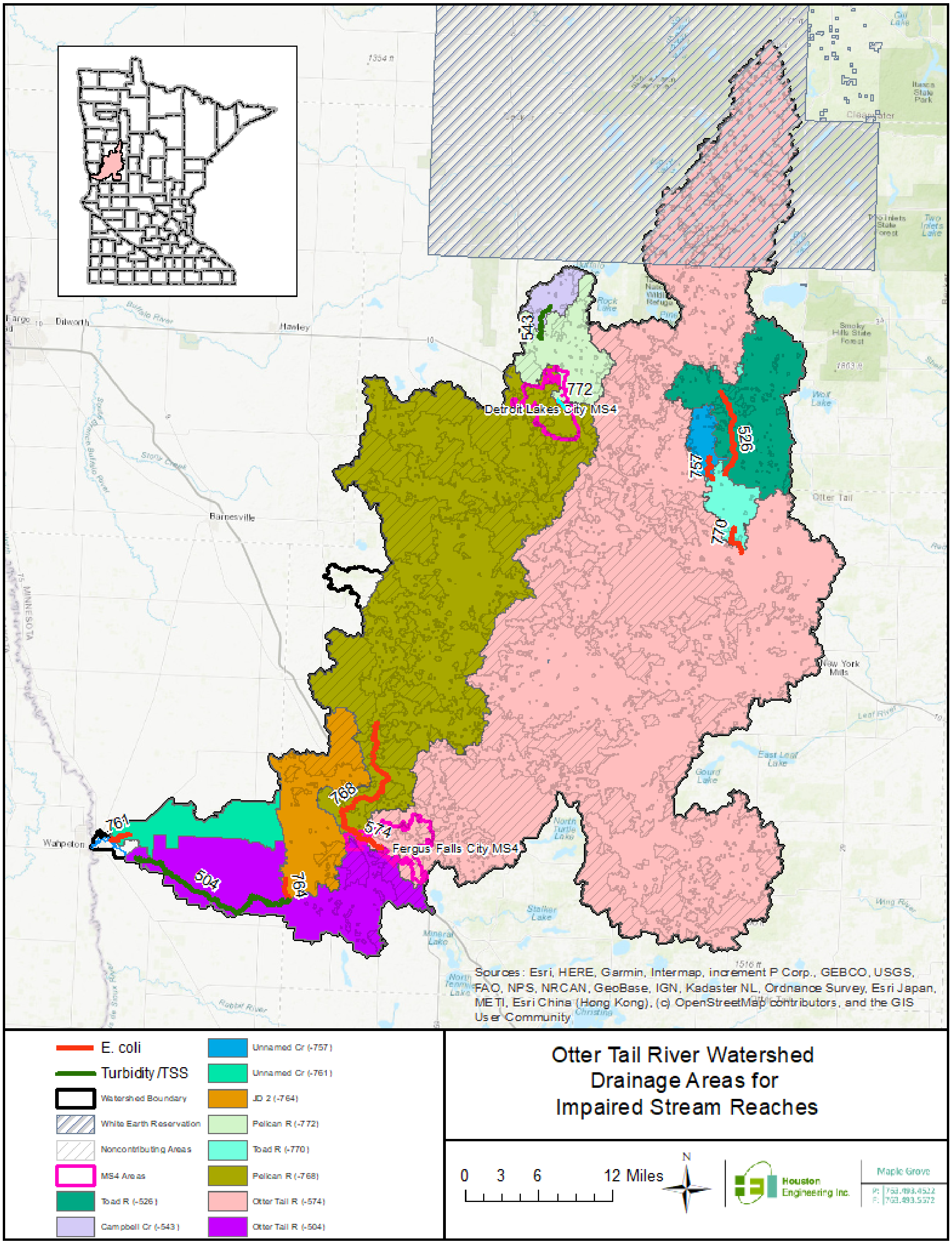

Figure 6. Drainage areas of impaired streams in the OTRW addressed in this TMDL report.

3.4 Land use/land cover

Land cover in the OTRW was evaluated using the 2011 NLCD (MRLCC 2011). Data from 2011 is provided since it matches the land use applied to develop the HSPF model. This information is necessary to draw conclusions about pollutant sources that may be applicable in each impaired stream reach and lake. The land use distribution for the watershed and the impaired stream reaches and lakes is provided in **Table 7** and shown in **Figure 7**. Land use and land cover in the OTRW was further discussed in **Section 3** watershed and waterbody characterization.

Table 7. Distribution of drainage area land cover by impaired stream and impaired lake addressed in this TMDL report.

WID	Waterbody Name	Drainage Area [sq. mi.]	Land Use/Land Cover Percentage of Drainage Area [%]						
			Crop land	Range land	Developed	Wetland	Water	Forest/ Shrub	Barren/ Mining
Watershed		1,952	26.9%	17.8%	5.7%	6.7%	14.8%	28.0%	0.06%
09020103-504	Otter Tail R.	1,870	25.6%	18.2%	5.6%	6.8%	15.1%	28.6%	0.06%
09020103-526	Toad R.	82.5	7.7%	27.9%	4.1%	9.2%	5.6%	45.5%	0.10%
09020103-543	Campbell Cr.	12.9	23.0%	21.7%	4.5%	12.3%	4.0%	34.1%	0.42%
09020103-574	Otter Tail R.	1,197	19.1%	18.7%	5.3%	7.6%	15.8%	33.4%	0.04%
09020103-757	Unnamed Cr	11.5	6.8%	26.6%	3.5%	20.7%	1.6%	40.7%	0.17%
09020103-761	Unnamed Cr	34.6	92.7%	0.1%	6.3%	0.5%	0.1%	0.3%	0.0%
09020103-764	JD 2	66.7	75.4%	6.0%	5.0%	4.5%	6.1%	3.0%	0.01%
09020103-768	Pelican R.	494	22.3%	21.5%	6.6%	6.1%	16.9%	26.5%	0.12%
09020103-770	Toad R.	112	10.4%	28.0%	3.9%	10.1%	4.7%	42.9%	0.10%
09020103-772	Pelican R.	56.1	13.7%	23.9%	8.2%	9.2%	7.6%	37.2%	0.33%
03-0398-00	Wine	0.26	16.1%	25.3%	12.2%	2.2%	22.0%	22.2%	0.0%
56-0210-00	Long	4.35	15.0%	16.8%	3.6%	4.9%	39.1%	20.6%	0.0%
56-0458-00	Crooked	1.88	34.7%	22.6%	5.8%	3.1%	15.7%	18.1%	0.0%
56-0502-00	West Spirit	0.87	4.2%	13.0%	2.8%	0.0%	45.4%	34.4%	0.0%
56-0569-01	Norway East	1.56	32.5%	9.2%	1.5%	2.3%	43.9%	10.5%	0.0%
56-0569-02	Norway W.	3.47	44.2%	27.2%	4.8%	4.1%	10.4%	9.3%	0.0%
56-0791-00	Unnamed	1.19	58.0%	5.0%	4.1%	1.7%	30.5%	0.8%	0.0%
56-0882-00	Devils	2.55	27.1%	29.6%	3.3%	2.4%	26.0%	11.6%	0.0%
56-0907-00	Grandrud	0.86	12.8%	23.8%	4.9%	4.2%	23.0%	31.3%	0.0%
56-0979-00	Johnson	1.85	48.3%	0.8%	5.8%	2.9%	38.1%	4.1%	0.0%
56-0982-00	Oscar	14.72	66.7%	7.7%	6.2%	1.9%	15.6%	1.9%	0.0%
56-1014-00	Hovland	3.24	59.0%	6.0%	3.8%	5.5%	15.1%	10.7%	0.0%
56-1525-00	Twin	1.25	36.3%	7.7%	3.7%	8.9%	32.9%	10.5%	0.0%

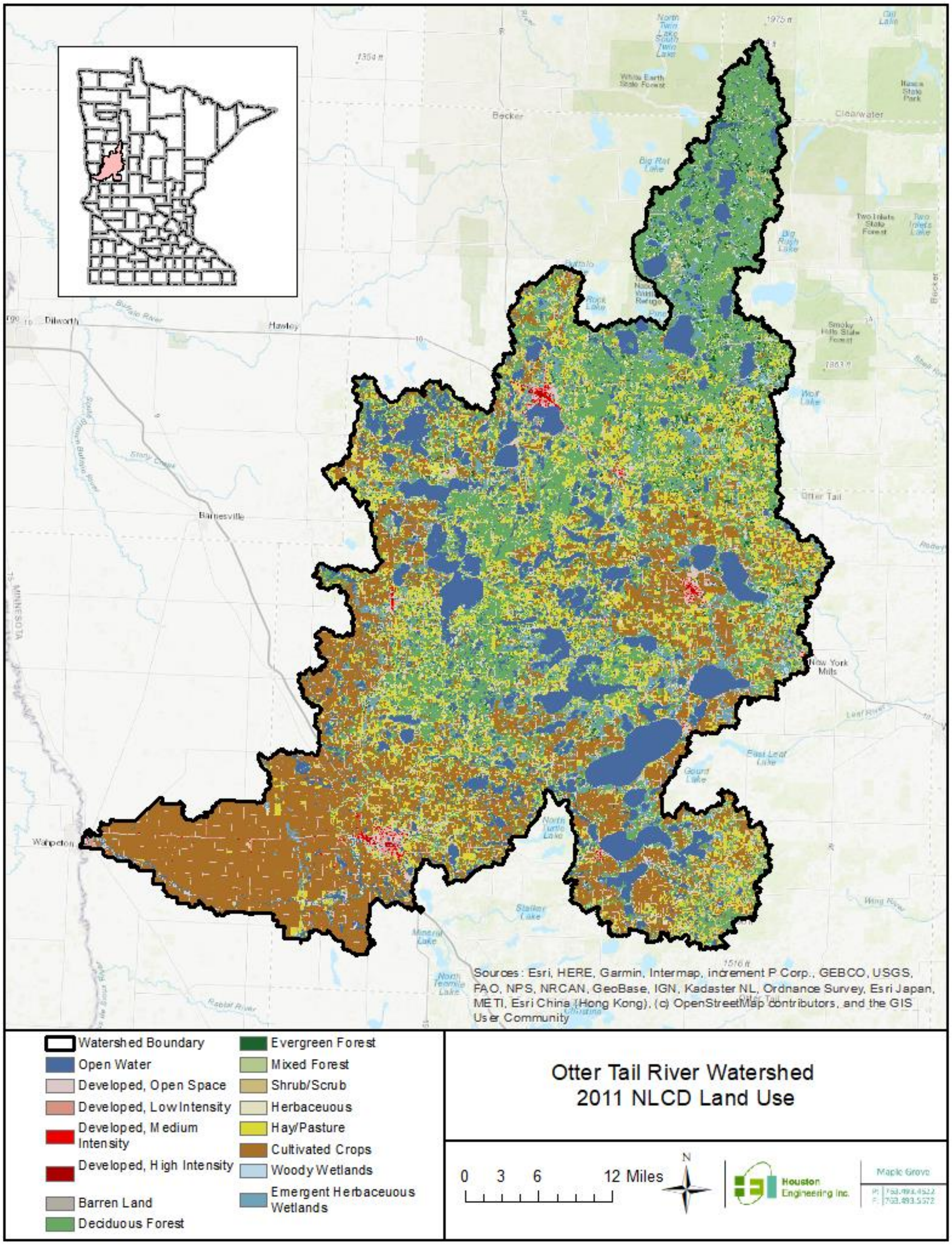

Figure 7. Land use/land cover in the OTRW.

3.5 Current/historical water quality

Existing water quality conditions are described using data downloaded from the MPCA's Environmental Quality Information System (EQuIS) database (MPCA 2020b). EQuIS stores data collected by the MPCA, partner agencies, grantees, and citizen volunteers. All water quality sampling data utilized for assessments, modeling, and data analysis for this report and reference reports, are stored in this database and are accessible through the MPCA's Environmental Data Access (EDA) website (MPCA 2020c).

Mostly, data from the applicable 10-year assessment period (2008 through 2017), consistent with the time period for the application of the water quality numeric standards, were used for development of this TMDL report. Occasionally and when available, data from 2018 were also used for the development of some TMDLs, to include the most recently available data for those waterbodies at that time. Although data prior to 2008 exists, the more recent data represents the current conditions in the waterbody. However, for some locations, data prior to 2008 was used to get a better understanding of the water quality conditions and include more data in the development of the LDCs (see **Section 4.2.1** for information on LDCs). For *E. coli*, only data collected during the months of April through October for all streams were used. For TSS, data collected during the months of April through September were used. For Class 2B lakes, eutrophication data for June through September were used.

Various agencies and local partners, such as the MPCA, Soil and Water Conservation Districts (SWCDs), local watershed districts (WDs), and volunteer monitoring programs collected data used to develop this TMDL report. See **Section 7** for more information on monitoring programs**.** Monitoring locations used for this TMDL report are shown in **Figure 8** and are summarized for the applicable 10-year assessment period (2008 through 2017) in **Table 8** (*E. coli*), **Table 9** (TSS), and **Table 10** (lake nutrients).

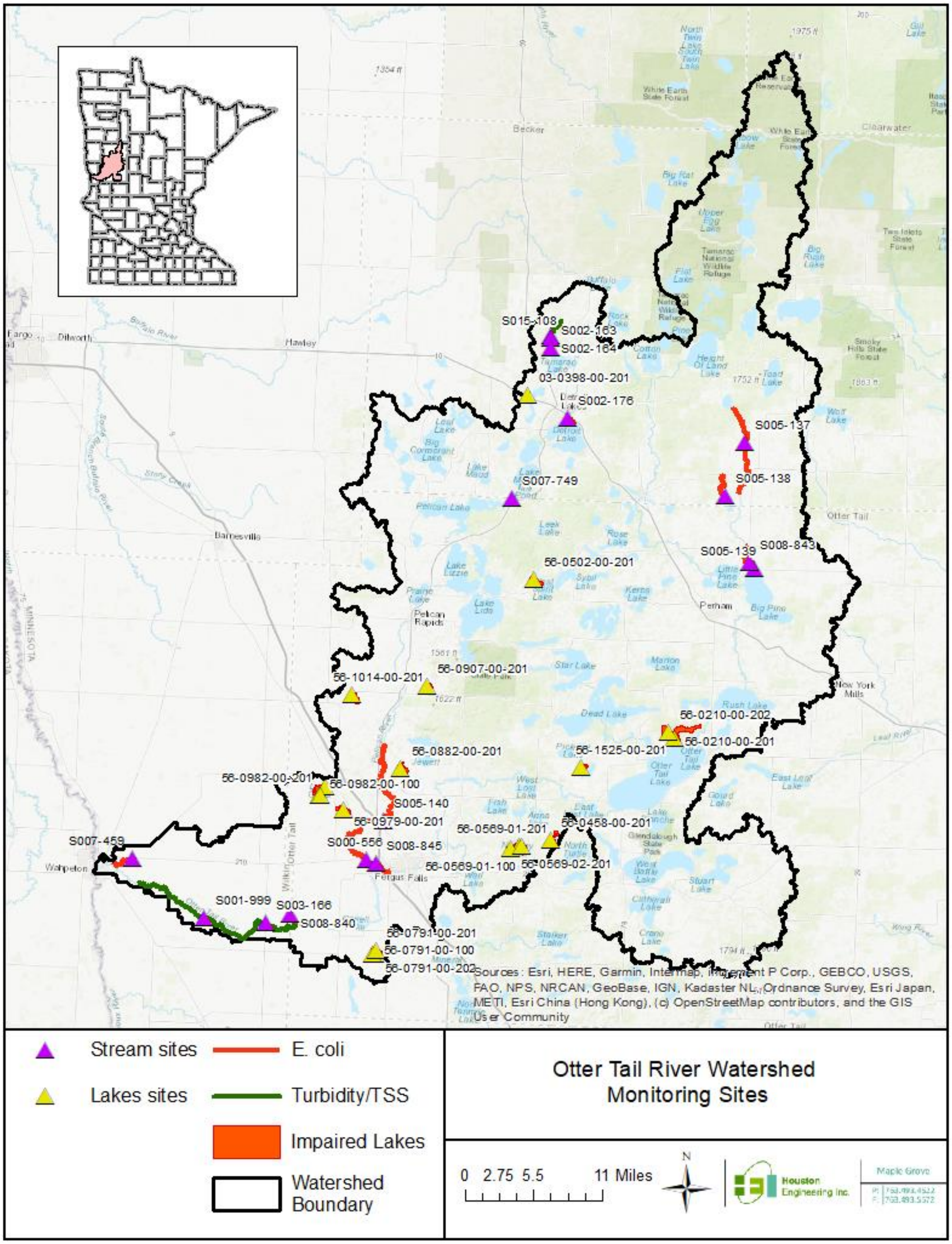

Figure 8. Monitoring locations used in this TMDL Report.

3.5.1 *Escherichia coli*

E. coli is summarized using the geometric mean of all samples in a calendar month. The geometric mean better normalizes data from different flow conditions, as may occur during low flow events and storm events, and allows a percentage change to be made equally to the geometric mean across watersheds. The geometric mean can be calculated using the following function:

$$\text{Geometric mean} = \sqrt[n]{x_1 * x_2 * \dots x_n}$$

Where $x_1, x_2, \dots, x_n$ are *E. coli* concentrations with a single sampling month.

The impairments caused by *E. coli* are based on the monthly geometric mean, not to exceed 126 org/100mL with no less than five samples within any calendar month, or no more than 10% of all samples of any calendar month exceeding 1,260 org/100mL. The standard applies only between April 1 and October 31. **Table 8** shows the monthly *E. coli* statistics (number of samples, geometric mean, and percentage of samples above 1,260 org/100 mL) for reaches in the OTRW addressed in this TMDL report.

Table 8. Current *E. coli* conditions in impaired stream reaches addressed in this TMDL report.[1]

WID (Stream/Reach Name)	Station(s)	Years	April			May			June			July			August			September			October		
			n	Geo	%n> 1260	n	Geo	%n> 1260	n	Geo	%n 1260	n	Geo	%n> 1260	n	Geo	%n> 1260	n	Geo	%n> 1260	n	Geo	%n> 1260
09020103-526 (Toad R, Little Toad Lk to T138 R38W S30, SW corner)	S005-137	2008-2010	0			0			5	**160**	0%	5	**176**	0%	5	**131**	0%	3	**168**	0%	0		
09020103-574 (Otter Tail R, Unnamed lk (56-0821-00) to Pelican R)	S008-845	2016-2017	0			0			5	56	0%	5	79	0%	5	**240**	0%	0			0		
09020103-757 (Unnamed cr, Unnamed cr to Dead Lk)	S005-138	2008-2010	0			0			5	**422**	0%	5	**569**	**20%**	5	**923**	**40%**	3	**2266**	**100%**	0		
09020103-761 (Unnamed cr, CD 3 to Otter Tail R)	S007-459	2013-2018	2	3.7	0%	3	**277**	0%	8	**243**	**25%**	6	**399**	**17%**	6	95	**17%**	2	52	0%	2	17	0%
09020103-764 (JD 2, Unnamed ditch along 190th St to Otter Tail R)	S008-840	2016-2017	0			0			5	106	0%	5	**320**	**20%**	5	**391**	**20%**	0			0		
09020103-768 (Pelican R, Reed Cr to Otter Tail R)	S000-556	2008-2017	0			0			10	**151**	10%	10	**136**	0%	10	**190**	0%	3	**164**	0%	0		
	S005-140	2008-2010	0			0			5	**131**	0%	5	109	0%	6	123	0%	3	**181**	0%	0		
09020103-770 (Toad R, Unnamed cr to Pine Lk)	S005-139	2008-2010	0			0			5	100	0%	6	**210**	0%	5	75	0%	3	**151**	0%	0		
	S008-843	2016-2017	0			0			5	79	0%	5	**194**	0%	5	74	0%	0			0		
09020103-772 (Pelican R, Highway 10 to Detroit Lk)	S002-176	2016-2017	0			0			5	**131**	0%	5	**446**	**40%**	5	**136**	0%	0			0		

[1]n = number of samples; Geo = geometric mean; %n>1260 = percentage of samples above 1,260 org/100mL. Bold entries denote exceedance of standard(s).

3.5.2 Total Suspended Solids

The impairments caused by TSS are based on having no more than 10% of all applicable samples in the applicable 10-year assessment period exceed the current TSS standard of 30 mg/L for the CRNR. TSS data is summarized for the TSS-impaired reaches requiring TMDLs in the OTRW in **Table 9**.

Table 9. Current TSS conditions in impaired stream reaches addressed in this TMDL report.

WID (Stream Name)	Station	Period	Number of samples	90th Percentile [mg/L]	Number of Exceedances	Percentage of Exceedances[1]
09020103-504 (Otter Tail R.)	S001-999	2017-2018	6	27	0	0%
	S003-166	2009-2018	31	32	4	13%
09020103-543 (Campbell Cr.)	S002-163	2005-2018	145	115	57	39%
	S002-164	2005-2018	150	65	27	18%
	S015-108	2018-2018	12	32	2	16%

[1]Water quality standard allows no more than 10% of applicable samples to exceed the numeric standard.

3.5.3 Lake Nutrients

In general, historical in-lake water quality data collected from the period 1996 through 2018 were reviewed and summarized for use in this TMDL report. Although data from 2008 through 2017 was used in the assessment process to determine impairment, the period 1996 through 2008 was used to summarize water quality conditions to be consistent with the lake modeling effort, which was used to determine the LC (see **Section 4.4.1**). **Table 10** provides the number of samples and average (mean) measurements during the summer (June through September) for TP, Chl-*a*, and Secchi Disk depths. The lake nutrient impairments are based on summer averages of TP and at least one of the response variables, Chl-*a* or Secchi depth, exceeding the standards for NCHF shallow lakes (TP not more than 60 micrograms per liter (µg/L), Chl-a not more than 20 µg/L, and Secchi depth not less than 1.0 meter).

Table 10. Current lake nutrients conditions in impaired lakes addressed in this TMDL report.[1]

Lake Name	WID -Station ID(s)	Observation Period	TP [µg/L]		Chl-*a* [µg/L]		Secchi Disk Depth [m]	
			n	Average	n	Average	n	Average
Wine	03-0398-00-201	2008-2010, 2012	23	**100**	20	**30**	22	**0.779**
Long	56-0210-00-201, 56-0210-00-202	2016-2018	23	**126**	23	**54**	24	**0.464**
Crooked	56-0458-00-201	2011-2012	10	**83**	10	**58**	10	**0.850**
West Spirit	56-0502-00-201	2000-2007	38	**72**	38	**28**	38	1.138
Norway (East Bay)	56-0569-01-100, 56-0569-01-201	2011-2012, 2017-2018	20	**132**	20	**29**	46	3.083
Norway (West Bay)	56-0569-02-201	2011-2012	10	**162**	10	**31**	10	1.800
Unnamed	56-0791-00-201, 56-0791-00-202	2011-2012, 2014	11	**197**	11	**109**	11	**0.355**
Devils	56-0882-00-201	2011-2012	10	**100**	10	**50**	10	1.210
Grandrud	56-0907-00-201	2011-2012	11	**61**	11	**25**	10	**0.740**
Johnson	56-0979-00-201	2011-2012	10	**98**	10	**46**	10	**0.420**
Oscar	56-0982-00-202	2003, 2008, 2011-2012	10	**151**	8	**54**	10	1.172
Hovland	56-1014-00-201	2011-2012	12	**185**	12	**43**	10	1.530
Twin	56-1525-00-201	2011-2012	10	**140**	10	**61**	9	**0.522**

[1]Bold entries denote averages that exceed standard.

3.6 Pollutant source summary

Sources of pollutants in the OTRW include permitted and nonpermitted sources. The permitted sources discussed here are pollutant sources that require a NPDES permit. Nonpermitted sources are pollutant sources that do not require an NPDES permit. Most Minnesota NPDES permits are also SDS permits (i.e., NPDES/SDS permit). Some pollutant sources require SDS permit coverage alone without NPDES permit coverage, such as spray irrigation, large septic systems, land application of biosolids and industrial by-products, and some feedlots.

The phrase "nonpermitted" does not indicate that the pollutants are illegal, but rather that they do not require an NPDES or SDS permit. Some non-permitted sources are unregulated, and some nonpermitted sources are regulated through non-NPDES programs and permits, such as state and local regulations.

3.6.1 *Escherichia coli*

E. coli bacteria in Minnesota lakes and streams mainly come from sources such as failing septic systems, WWTP releases, livestock, pets, wildlife, and urban stormwater. In addition to *E. coli*, human and animal waste may contain pathogens such as viruses and protozoa that could be harmful to humans and other animals.

The behavior of *E. coli* and pathogens in the environment is complex. Levels of *E. coli* and pathogens in a body of water depend not only on their source, but also weather, current, and water temperature. As these factors fluctuate, the level of *E. coli* and pathogens in the water may increase or decrease. Some *E. coli* bacteria can survive and grow in the environment, while other bacteria and many pathogens tend to die off with time.

A literature review conducted by Emmons and Oliver Resources (EOR 2009) for the MPCA summarizes factors that have either a strong or a weak positive relationship to bacteria (including *E. coli*) contamination in streams (**Table 11**). Bacteria sourcing can be very difficult due to the bacteria's ability to persist, reproduce, and migrate in unpredictable ways. Therefore, the factors associated with bacterial presence provide some confidence to bacterial source estimates.

Table 11. Summary of factor relationships associated with bacteria source estimates of streams (EOR 2009).

Strong relationship to fecal bacteria contamination in water	Weak relationship to fecal bacteria contamination in water
• High storm flow (the single most important factor in multiple studies); • % rural or agricultural areas greater than % forested areas in the landscape; • % urban areas greater than forested riparian areas in the landscape; • High water temperature; • High % impervious surfaces; • Livestock present; • Suspended solids.	• High nutrients • Loss of riparian wetlands • Shallow depth (bacteria decrease with depth) • Amount of sunlight (increased UV-A deactivates bacteria) • Sediment type (higher organic matter, clay content and moisture; finer-grained) • Soil characteristics (higher temperature, nutrients, organic matter content, humidity, moisture and biota; lower pH) • Stream ditching (present or when increased) • Epilithic periphyton present • Presence of waterfowl or other wildlife • Conductivity

E. coli produced in the OTRW was estimated for the drainage area of each impaired reach using available *E. coli* data on livestock and manure application, pasture area, human populations (WWTPs and subsurface sewage treatment systems [SSTS]), pet density, and wildlife populations based on literature rates from previous studies on sources. In addition, microbial source tracking (MST) was conducted during the summer of 2019 in impaired stream reaches to identify potential sources of *E. coli*. Assessing the number of *E. coli* generated by major sources in the watershed can aid in implementing conservation activities to reduce *E. coli* loading to surface waters.

3.6.1.1 Microbial Source Tracking

MST was used in the OTRW to attempt to determine sources of *E. coli* in impaired stream reaches. The MST method used in the OTRW analyzes *E. coli* DNA to determine the potential source of *E. coli* bacteria found in the stream. Two water samples were collected over two sampling dates (July 10, 2019 and August 29, 2019) at 10 locations covering 8 stream reaches that are impaired due to *E. coli*. The 20 total water samples were then delivered to RMB Environmental Laboratories (RMB) in Detroit Lakes, Minnesota, where the first of the two samples was analyzed to determine *E. coli* concentrations at each of the 10 sampling locations. The second of the two samples were then prepped at RMB and shipped to Source Molecular Laboratory in Miami Lakes, Florida, for MST testing and analysis. If RMB's *E. coli* results were found to exceed 126 org/100 mL (see results in **Table 12**), then RMB informed the Source Molecular lab that those corresponding samples in the second set should be further analyzed for potential sources of the *E*. *coli*, while those samples resulting in less than 126 org/100 mL could be discarded. Each sample exceeding 126 org/100 mL was analyzed against four or five pre-selected targets (humans or animal types) based on drainage area characteristics of each impaired stream reach. The results of MST are also shown in **Table 12**.

A quantifiable result for an identified target indicates a strong presence of fecal bacteria from that particular target in the drainage area, and suggests that target was a source of fecal contamination at the time of sample collection and may contribute to the impairment caused by excessive *E*. *coli*. Results reported as "DNQ" (Detected Not Quantified) suggest a presence of fecal bacteria from that particular target, but at a low level. Results reported as "ND" (Not Detected) means that MST was attempted with those targets, but fecal bacteria from those targets were absent from the drainage area at the time of sample collection and those targets are not suggested as a potential contributor.

Table 12. Results of microbial source tracking (MST) on reaches impaired due to excessive *E. coli*.

Sample Date	Station ID	WID[1]	*E. coli* [org/ 100 mL]	MST Target*							
				Bird Fecal ID [copies / 100mL]	Dog Fecal ID [copies / 100mL]	Human Fecal ID (Dorei) [copies / 100mL]	Human Fecal ID (EPA) [copies / 100mL]	Cow Fecal ID [copies / 100mL]	Beaver Fecal ID [copies / 100mL]	Goose Fecal ID [copies / 100mL]	Poultry Litter Fecal ID [copies / 100mL]
7/10/2019	S005-137	526	980.4			DNQ	ND	DNQ	DNQ		
	S008-845	574	111.2 [2]								
	S005-138	757	1,732.9			DNQ	ND	710	DNQ		
	S007-459	761	177.5	7,450		DNQ	ND	ND			
	S008-840	764	214.1	12,500		DNQ	ND	ND			
	S000-556	768	816.4	DNQ		ND	ND	ND			
	S005-140	768	118.7 [2]								
	S005-139	770	275.5			DNQ	ND	ND	DNQ		
	S008-843	770	240.0			DNQ	DNQ	ND	DNQ		
	S002-176	772	1,413.6	6,500	DNQ	DNQ	ND		DNQ		
8/29/2019	S005-137	526	58.3 [2]								
	S008-845	574	88.6 [2]								
	S005-138	757	416	995		ND		263			
	S007-459	761	88.4 [2]								
	S008-840	764	613.1	5,650		ND		ND		ND	
	S000-556	768	160.7	DNQ		ND		ND		ND	
	S005-140	768	111.2 [2]								
	S005-139	770	38.4								
	S008-843	770	73.3								
	S002-176	772	150	12,800	DNQ	683				ND	ND

*DNQ = Detected Not Quantified; ND = Not Detected, and a blank cell indicates that MST was not attempted for that target.

[1]Last 3-digits of WID

[2] The *E. coli* concentration was below the 126 org/100mL threshold, so MST was not performed on these samples.

Results from the MST show fecal bacteria from birds detected in five streams, dogs in one stream, human in seven streams, cows in two streams, and beavers in five streams. Bird fecal bacteria was quantified in four of the five streams where it was present, human fecal coliform was quantified in one stream, and cow fecal coliform was quantified in one stream. The results suggest that birds, humans, cattle, and beavers are potential sources of *E. coli* within the drainage areas of the impaired stream reaches.

It should be noted that these results only represent specific points in time and other sources may contribute to the *E*. *coli* impairments that were not tested for or were not present during sample collection. It is best to perform MST analysis on many water samples, during multiple applicable months, under a variety of flow conditions, and with as many fecal bacteria targets as possible to better infer the sources of fecal contamination. Furthermore, there is always the possibility that MST analysis produces false positive or false negative results. A false positive result occurs when analysis incorrectly indicates the fecal bacteria came from a certain target source when in fact that target source did not contribute fecal contamination within the drainage area. A false negative result occurs when analysis incorrectly indicates that the absence of fecal bacteria from a certain target source when that target source is actually contributing fecal contamination within the drainage area. For example, a false negative may occur when the short pieces of DNA used for cow MST analysis do not perfectly match the DNA of the fecal bacteria from cows in the OTRW. Finally, both rounds of testing were conducted during periods of high stream flow, with the first round of testing occurring concurrent with a rain event and with the second round of testing occurring during cooler temperatures in August. Having more testing and having a round of testing during periods of low stream flow and/or warmer late-summer temperatures may have provided different MST results. It was a goal of this project to have two contrasting rounds of sampling; however, summer 2019 precipitation and weather conditions did not allow that. For these reasons, the MST results are provided in this TMDL report as informational only and are not used in any TMDL allocations or related permit requirements.

Potential sources of *E. coli* in the OTRW are further discussed below.

3.6.1.2 Permitted sources

Animal Feedlots

Feedlots and manure storage areas can be a significant source of *E. coli* due to runoff from the animal holding areas or the manure storage areas. In Minnesota, animal feedlot operators are required under Minn. R. 7020.0350, to register their feedlot or manure storage area at least once in a four-year period with the county feedlot officer if the county is delegated, or with the MPCA if the county is nondelegated. Feedlot operators must register their facility if they are 1) an animal feedlot capable of holding 50 or more animal units (AUs), or a manure storage area capable of holding the manure produced by 50 or more AUs; and/or 2) an animal feedlot capable of holding 10 or more and fewer than 50 AUs, or a manure storage area capable of holding the manure produced by 10 or more and fewer than 50 AUs, that is located within shoreland. Shoreland is defined by Minn. R. 7020.0300, subp. 21, as land located within 1,000 feet from the normal high water mark of a lake and land within 300 feet of a river or stream.

Concentrated Animal Feeding Operation (CAFO) is an EPA definition that implies not only a certain number of animals but also specific animal types. According to the EPA definition, CAFOs can be classified by size and includes classifications of large, medium, and small, based on number of animals (head count)[2]. Large CAFOs follow the EPA's CAFO definition (e.g. equal to or more than 2,500 swine or 1,000 cattle). Medium CAFOs animal counts range between 750 to 2,499 swine or 300 to 999 cattle. Small CAFOs are classified as having less than 750 swine or 300 cattle. The animal count numbers vary by type of animal and size. Definitions can be found at the link in the footnote.

The MPCA currently uses the federal definition of a CAFO in its permit requirements of animal feedlots along with the definition of AU. In Minnesota, the following types of livestock facilities are issued, and must operate under, a NPDES permit or a state issued SDS permit: a) all CAFOs and non-CAFOs that have 1,000 or more AUs; or b) all federally defined CAFOs which have had a discharge, some of which are under 1,000 AUs in size. CAFOs with less than 1,000 AU and that have not had a discharge may choose to operate without a NPDES permit. Manure management planning, record keeping, and land application requirements are generally more stringent for these feedlots than for smaller feedlots, in accordance with Minn. R. 7020.2225 and the respective Permit. Furthermore, NPDES permitted CAFOs must be designed to totally contain all manure, manure contaminated runoff, and process wastewater from precipitation events of less than a 25-year, 24-hour storm event. Having and complying with an NPDES permit allows some enforcement protection if a facility discharges due to a precipitation event greater than or equal to a 25-year, 24-hour precipitation event and the discharge does not contribute to a water quality impairment. Large CAFOs permitted with an SDS permit or those with less than 1,000 AU that have chosen to forego NPDES permit coverage must contain all runoff, regardless of the precipitation event. Therefore, many large CAFOs in Minnesota have chosen to obtain an NPDES permit, even if discharges have not occurred in the past at the facility.

CAFOs are inspected by the MPCA in accordance with the MPCA NPDES Compliance Monitoring Strategy approved by the EPA. All CAFOs (NPDES permitted, SDS permitted, and not required to be permitted) are inspected by the MPCA on a routine basis with an appropriate mix of field inspections, offsite monitoring, and compliance assistance. All non-CAFOs are inspected in delegated counties by the county feedlot officer on a routine basis in accordance with the delegated county's Delegation Agreement and Work Plan, which is prepared with and approved by the MPCA every-other year. Non-CAFOs in nondelegated counties are inspected by MPCA on an as-needed or complaint-driven basis. In the OTRW, Clay County is the only delegated county while Otter Tail, Becker, Wilkin, Clearwater, and Mahnomen are all nondelegated counties. For more information on the MPCA's Feedlot Program see **Section 6.2.2**.

According to the MPCA's "Feedlots in Minnesota" Geographic Information Systems (GIS) layer (MPCA 2020d), there are 499 feedlots in the OTRW that are either currently registered or have been registered at any one time but now may be inactive. Of the 499 feedlots, 303 are currently required to be registered with 50 or more AU outside of shoreland or 10 or more AU within shoreland. The 303 feedlots have a recorded total of 72,933 AUs, with the majority being dairy and beef cattle (61%), and the rest being birds (32%), or pigs (7%). Of the 303 required to register (**Figure 9**), 9 are permitted CAFOs and 2 are CAFOs without permits, 236 are designated as having livestock housed on or having access to

[2] https://www3.epa.gov/npdes/pubs/sector_table.pdf

open feedlots, and 234 are designated as having livestock housed on or having access to pasture. The 11 CAFOs account for 17.7% (12,910 AUs) of the total AUs in the watershed and are mostly turkeys.

Furthermore, 52 of the 303 are located within shoreland, and 49 of those 52 are designated as having open lot feedlots in a shoreland area. Open lots and other feedlots and manure storage areas located near surface waters present a potential pollution hazard if runoff from the lot or manure storage area is not treated or filtered prior to reaching a surface waterbody.

For the OTRW TMDL, all NPDES and SDS permitted feedlots must be designed and operated to have zero discharge, and as such they are not considered a significant source of *E. coli* to the OTRW. All other feedlots are accounted for as nonpermitted sources. The land application of all manure, regardless of whether the source of the manure originated from permitted or nonpermitted feedlots, is also accounted for as a nonpermitted source. Nonpermitted sources are further discussed in **Section 3.6.1.3**.

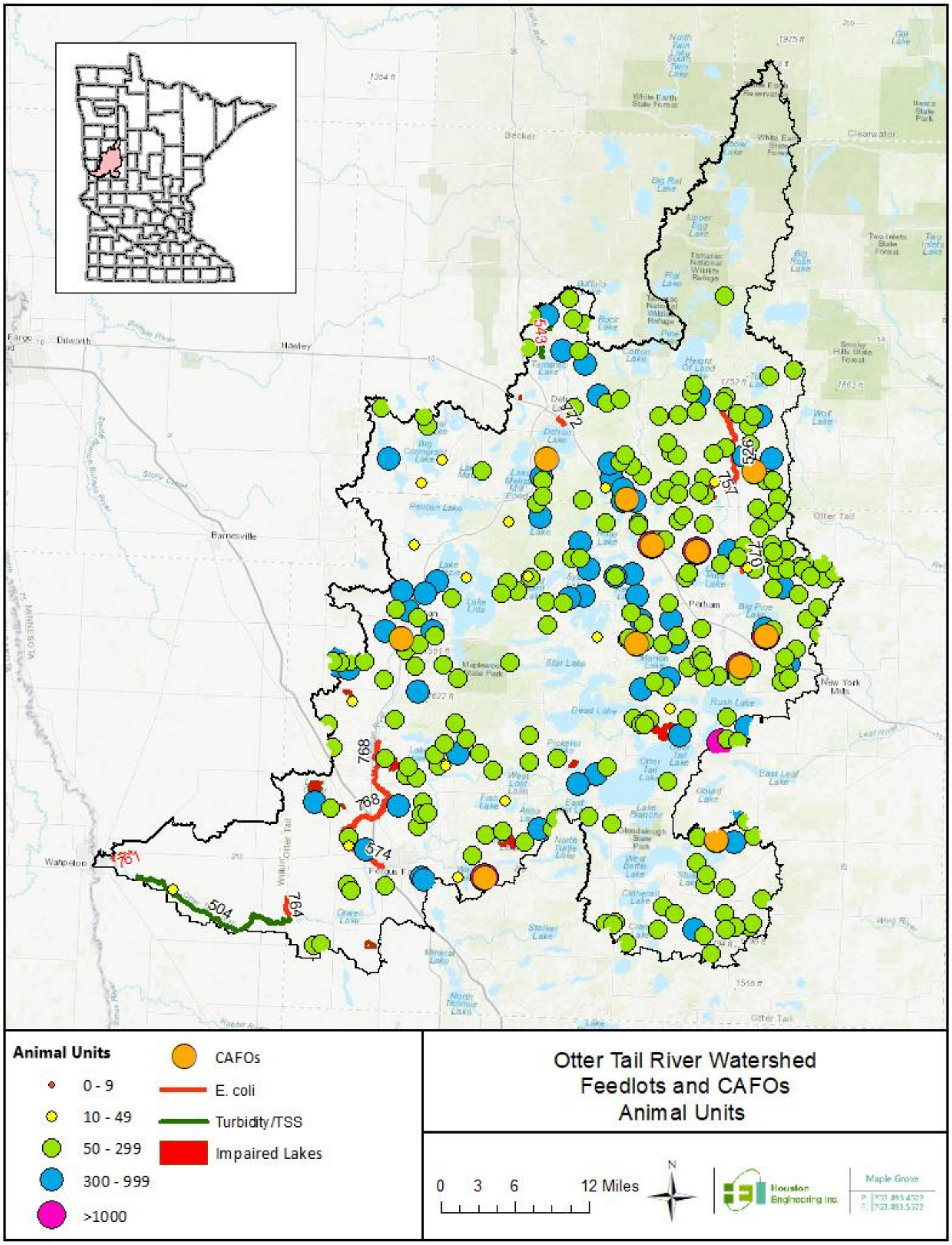

Figure 9. Feedlots in the OTRW.

Domestic and Industrial Wastewater

Human waste can be a significant source of *E. coli* during low flow periods. There are 17 active NPDES/SDS domestic and industrial wastewater discharge permits in the OTRW; 7 are domestic wastewater permits and 10 are industrial wastewater permits. Some of these permitted facilities have multiple discharge locations. Of the seven domestic wastewater permits, two permitted facilities, Elizabeth WWTP and Fergus Falls WWTP, discharge into or within a natural boundary condition area applied for river reaches that are impaired due to *E. coli* and are considered to be potential sources of *E. coli* to those impaired reaches (see **Section 4.2.3**). The remaining permitted facilities include four domestic WWTPs that discharge upstream of or outside of the natural boundary condition area applied for any impaired reach, one domestic WWTP that does not discharge to the OTRW, and the 10 industrial wastewater dischargers that are not considered to be sources of *E. coli*. The four domestic WWTPs that are upstream of the natural boundary condition area applied for any impaired reach include Cormorant Park Place Estates WWTP, Detroit Lakes WWTP, Pelican Rapids WWTP, and Vergas WWTP. These WWTPs are not considered to be potential sources of *E. coli* to the downstream impairments, because the numerous lakes and any river reaches that meet *E. coli* standards upstream of the boundary condition area are expected to assimilate the *E. coli* and minimize the impacts of the upstream waters on the impaired reaches (see **Section 4.2.3**). The WWTP that does not discharge to the OTRW, and therefore does not contribute pollutants to the OTRW, is the Forest Hills Golf and RV Resort WWTP (NPDES/SDS Permit Number MN0056685, Surface Discharge Station SD 001). Wastewater discharge from this facility does not leave the site as surface runoff; instead, discharge is stored in on-site ponds and ultimately used for irrigation (MPCA 2016). Although it is assumed that treated wastewater does not leave the site, there is a fecal coliform discharge limit on the permit's surface discharge station in the case the facility would need to discharge treated wastewater that leaves the site.

The permitted domestic WWTPs in the OTRW, including the two that are considered to be potential sources of *E. coli* to the impaired river reaches, include both controlled and continuous discharge systems. Controlled discharge systems, or pond systems, are permitted to discharge in the OTRW during windows from March 1 through June 30 and September 1 through December 31. Continuous discharge systems, or mechanical systems, are generally permitted to discharge throughout the year. While *E. coli* bacterial loads discharged by WWTPs can theoretically comprise a significant portion of a receiving water's LC during low flow periods, bacterial effluent limits in WWTP permits are intended to ensure that wastewater is effectively disinfected prior to discharge.

Rarely, during extremely high flow or precipitation conditions, WWTPs may be a source of *E. coli* if they become overloaded and have an emergency discharge of partially or untreated sewage, known as a wet weather release. When the excess water overwhelms the designed capacity of the collection system or the WWTP, the release may be necessary in order to protect wastewater infrastructure and avoid imminent public health threats associated with sewage backflow. Wet weather releases are often relatively dilute compared to untreated wastewater, although even dilute wastewater may contain *E. coli.* Because receiving waters are typically at high flows during wet weather events, the water quality impact of wet weather releases can be relatively minor. Conversely, dry weather releases, which are often due to mechanical failures, can deliver full strength wastewater to waterbodies during base flow or low flow, and the resulting water quality impacts can therefore be greater than those associated with wet weather releases.

A release is an unauthorized, prohibited overflow or spill of wastewater to the environment. When releases occur, the WWTP operator is required to immediately contact the Minnesota Duty Officer, discontinue the release as soon as possible, recover all substances and materials if possible, collect representative sample(s) of the release, and report sample results to the MPCA. In the OTRW, there have been seven reported releases that discharged to or upstream of river reaches that are impaired due to *E. coli* and that are relevant to this TMDL report. The reported releases occurred between the years of 2007 through 2016, with five of the releases occurring between the months of April through October, consistent with the applicable period of the *E. coli* water quality standard (MPCA 2021). The effect of these releases on *E. coli* concentrations in the impaired waters is not known; quantities, types, and treatment levels of the released wastewater, as well as weather and stream flow conditions, across the reported releases were variable and in some cases, unknown. Additional information and monitoring would be needed to further evaluate this source and its potential effect on water quality.

Municipal Stormwater Runoff

There are two NPDES/SDS permitted municipal separate storm sewer system (MS4) areas within the OTRW and both are partially within drainage areas of impaired stream reaches addressed in this TMDL report, Detroit Lakes (MS400230) and Fergus Falls (MS400268). The Detroit Lakes MS4 total area covers 15.17 square miles and the Fergus Falls MS4 total area covers 15.26 square miles. Drainage areas of three stream reaches impaired due to *E. coli* include at least part of one of the two MS4 areas. Percentages covered by the MS4 area in each impaired reaches' contributing watershed can be found in **Section 4.2.3**. Urban areas may contribute *E. coli* to surface waters from pet waste, wildlife, and other sources. Therefore, they are considered to be potential sources of *E. coli* to those impaired reaches. Permitted MS4s must follow the best management practices (BMPs) and reporting requirements as identified in their permits and Stormwater Pollution Prevention Plans (SWPPP).

Due to a natural boundary condition created by the numerous lakes and at least one river reach meeting *E. coli* standards upstream, further described in **Section 4.2.3**, the Detroit Lakes MS4 area does not receive a WLA for and is not considered to be a potential source of *E. coli* to the impaired reach of the Pelican River from Reed Creek to the Otter Tail River (WID 09020103-768). The Fergus Falls MS4 area is considered a potential source and receives a WLA for the Pelican River, Reed Creek to Otter Tail River (WID 09020103-768). However, no *E. coli* reductions are currently required since the impaired reach and monitoring location S000-556 are largely located upstream of the Fergus Falls MS4 area (see **Sections 3.5 and 4.2.7)**. To meet the MS4 WLA, *E. coli* loading from the applicable MS4 area does not need to be reduced but is not allowed to increase. If, in the future, loading increases or new potential sources of *E. coli* are introduced or developed within the applicable MS4 area, the WLA may not be met. This was not applied for the Fergus Falls MS4 for the Otter Tail River, Unnamed Lake (56-0821-00) to Pelican River (WID 09020103-574), and for the Detroit Lakes MS4 for the Pelican River, Highway 10 to Detroit Lake (WID 09020103-772), since those applicable MS4 areas are largely upstream of those impaired reaches.

3.6.1.3 Nonpermitted sources

Subsurface Sewage Treatment System

Noncompliant SSTS near waterways can be a source of fecal contamination to streams and lakes, especially during low flow periods when these sources continue to discharge, and runoff driven sources are not active. The MPCA differentiates between SSTS that are generally failing and those that are an imminent threat to public health and safety (ITPHS). Generally, failing SSTS are those that do not provide adequate treatment and may contaminate groundwater. For example, a system deemed failing to protect groundwater may have a functioning, intact tank and soil absorption system, but fails to protect groundwater by providing less than sufficient amount of unsaturated soil between where the wastewater is discharged and the groundwater or bedrock. SSTS considered ITPHS are severely noncompliant or were never designed to provide adequate raw sewage treatment. Examples include SSTS and straight pipe systems that transport raw or partially treated sewage directly to a lake, a stream, a drainage system, or ground surface (Minn. Stat. 115.55, subd. 1).

Counties are required to submit annual reports to the MPCA regarding SSTS within their respective county. Data reported is aggregate information by each county so the location of SSTSs are not known to the State of Minnesota. However, annual reports by counties within significant contributing areas to the watershed indicate that noncompliant SSTS that have an ITPHS in these counties range from 0.71 (Clay) to 4.67 (Otter Tail) systems per 1,000 acres, with Becker listed as unknown. These counties continue to invest in the education of landowners on the maintenance and impact failing systems can have on humans and wildlife. Additionally, counties continue to develop county-wide GIS databases for SSTS to facilitate outreach and inspection of failing systems, and to work with landowners on fixing or replacing noncompliant systems as further discussed in **Section 6.2.1**.

Due to the variable or unknown data regarding noncompliant ITPHS systems in the OTRW, and the limited MST resulting in human fecal contamination quantified in only one impaired stream reach and detected but not quantified in six impaired reaches, this source is of possible yet less significant concern in the OTRW and is accounted for with all other NPS in the TMDL LAs.

Manure Application and Nonpermitted Animal Feedlots

Manure can be a significant source of bacteria. Animal feeding operations and feedlots generally create a large amount of manure that is usually stockpiled on site or on crop fields, or stored in pits, tanks, or lagoons on site until field conditions and the crop rotation allow for applying the manure as a fertilizer. The timing of manure spreading, as well as the application rate and method, can decrease the likelihood of bacteria loading to nearby waterbodies, represented here as *E. coli*. Specifically, the spreading of manure on frozen soil in the late-winter is likely to result in surface runoff with precipitation and snowmelt runoff events. Deferring manure application until snow has melted and soils have thawed decreases overland runoff associated with large precipitation events. Injecting or incorporating manure is a preferred BMP to reduce the runoff of waste and associated *E. coli* as incorporating manure into the soil reduces the risk of surface runoff associated with large precipitation events.

Short-term manure stockpile sites on crop fields prior to land application are included in the land applied manure calculations as manure is conventionally stockpiled on the same field, or very near, to which it is applied. Manure stockpiled for more than a year must be registered with the MPCA as an animal feedlot (see short-term stockpile site definition in Minn. R. ch. 7020) but for the purposes of this TMDL report, all manure was assumed to be applied within one year.

Animal waste and the associated *E. coli* from nonpermitted feedlots and manure application can be delivered to surface waters from failure of manure storage areas, runoff from the feedlot facilities or manure stockpiles, or runoff from nearby fields where the manure is land applied. While a full accounting of the fate and transport of manure was not conducted for this project, a large portion of the manure is ultimately applied to the land surface and, therefore, this source is of possible concern in the

OTRW. Minn. R. 7020.2225 contains several requirements for land application of manure; however, there are no explicit requirements for *E. coli* treatment prior to land application.

Pasture

Livestock can contribute fecal contamination to waterbodies, as indicated by elevated *E. coli* concentrations, from poorly managed pasture lands that are overgrazed or through the direct access of livestock to surface waters. Poorly maintained pasture can have significant overland surface flow during heavy precipitation events resulting in manure transport from the pasture, especially where feeding structures or watering devices are located adjacent to riparian areas and waterbodies. Livestock with direct access to streams and lakes can defecate directly into the waterbody resulting in direct contamination. While a full accounting of livestock access to waterbodies or runoff from pastures was not conducted for this project, it is assumed that livestock grazing and pastures exist throughout the watershed. Additionally, the limited MST analyzed possible fecal contamination from cows in six of the eight stream reaches impaired due to *E. coli*, resulting in cow fecal contamination quantified in one impaired reach, detected but not quantified in one stream reach, and not detected in four of the impaired stream reaches. Therefore, this source is of possible concern in the OTRW.

Natural Background Sources

"Natural background" is defined in both Minnesota statute and rule. The CWLA (Minn. Stat. § 114D.15, subd. 10) defines natural background as "characteristics of the waterbody resulting from the multiplicity of factors in nature, including climate and ecosystem dynamics, that affect the physical, chemical, or biological conditions in a waterbody, but does not include measurable and distinguishable pollution that is attributable to human activity or influence." Minn. R. 7050.0150, subp. 4, states, "'Natural causes' means the multiplicity of factors that determine the physical, chemical, or biological conditions that would exist in a waterbody in the absence of measurable impacts from human activity or influence."

Natural background sources are inputs that would be expected under natural, undisturbed conditions. Natural background sources can include inputs from natural geologic processes such as soil loss from upland erosion and stream development, atmospheric deposition, and loading from forested land, wildlife, etc. However, for each impairment, natural background levels are implicitly incorporated in the water quality standards used by the MPCA to determine/assess impairment, and therefore natural background is accounted for and addressed through the MPCA's waterbody assessment process. Natural background conditions were evaluated within the source assessment portion of this study. These source assessment exercises indicate that natural background inputs in the OTRW are generally low compared to livestock, cropland, streambank, WWTPs, failing SSTSs, and other anthropogenic sources.

However, MST conducted in the OTRW during the summer of 2019 showed that fecal bacteria from birds and beaver were each present in five of the eight impaired stream reaches, suggesting that birds, beaver, and potentially other sources of wildlife may be sources of *E. coli* in the OTRW.

Based on the MPCA's waterbody assessment process and the TMDL source assessment exercises, although birds, beavers, and other wildlife may be sources, there is no evidence at this time to suggest that natural background sources are a main driver of any of the impairments and/or affect the waterbodies' ability to meet state water quality standards. For more discussion of how natural background sources are considered in the TMDL calculations see **Section 4.1**.

Naturalized E. coli

The relationship between *E. coli* sources and *E. coli* concentrations found in streams is complex, involving precipitation and flow, temperature, sunlight and shading, livestock management practices, wildlife contributions, *E. coli* survival rates, land use practices, and other environmental factors. Research in the last 15 years has found the persistence of *E. coli* in soil, beach sand, and sediments throughout the year in the north central United States without the continuous presence of sewage or animal sources. This *E. coli* that persists in the environment outside of a warm-blooded host is referred to as naturalized *E. coli* (Jang et al. 2017). Naturalized *E. coli* can originate from different types of *E. coli* sources, including natural background sources such as wildlife and human attributed sources such as pets, livestock, and human wastewater. Therefore, whereas naturalized *E. coli* can be related to natural background sources, naturalized *E. coli* is not always from a natural background source.

An Alaskan study (Adhikari et al. 2007) found that total coliform bacteria in soil were able to survive for six months in subfreezing conditions. Two studies near Duluth, Minnesota found that *E. coli* were able to grow in agricultural field soil (Ishii et al. 2010) and temperate soils (Ishii et al. 2006). A study by Chandrasekaran et al. (2015) of ditch sediment in the Seven Mile Creek Watershed in southern Minnesota found that strains of *E. coli* had become naturalized to the water−sediment ecosystem. Survival and growth of fecal coliform has been documented in storm sewer sediment in Michigan (Marino and Gannon 1991), and *E. coli* regrowth was documented on concrete and stone habitat within an urban Minnesota watershed (Burns & McDonnell Engineering Company, Inc. 2017). This ability of *E. coli* to survive and persist naturally in watercourse sediment can increase *E. coli* counts in the water column, especially after resuspension of sediment (e.g., Jamieson et al. 2005).

The MPCA does not currently use any methods as standard practice to estimate (using an equation or model) or measure (using a laboratory analysis) what proportion of *E*. *coli* is naturalized. While a measurement would be preferable over an estimate, it is also more expensive, because it involves a laboratory component. The adaptation and evolution of naturalized *E*. *coli* that allows it to survive and reproduce in the environment makes it physically and genetically distinct from *E*. *coli* that cannot survive outside of a warm-blooded host. Laboratory methods target those physical and genetic differences and quantify their presence to provide a measurement. The MPCA is developing and piloting a protocol for the use of laboratory analyses to track *E. coli* to their source(s) (i.e., MST); these approaches may shed light on naturalized *E. coli*.

3.6.2 Total Suspended Solids

TSS consist of soil particles, algae, and other materials that are suspended in water and cause a lack of clarity. Excessive TSS can harm aquatic life and degrade aesthetic and recreational quality. External sources of TSS to streams and lakes include sediment loading from permitted sources outside the stream or lake such as construction, industrial, and municipal stormwater runoff, as well as wastewater effluent, and from nonpermitted sources such as overland erosion and atmospheric deposition. Sources of TSS that occur internally within a stream include sediment from bank erosion, scouring, and in-channel algal production. Sources of TSS are variable seasonally as the majority of sediment loading to waterbodies occurs during the spring snowmelt or during precipitation events. Erosion and sediment loss is most likely during heavy precipitation events on soil that is exposed or unprotected.

3.6.2.1 Permitted sources

Domestic and Industrial Wastewater

Domestic or industrial wastewater sites can be a source of TSS. Permitted WWTPs have strict TSS restrictions/limits that commonly contribute little to the permitted daily load of a particular waterbody. Due to a human-made boundary condition created by the Orwell Reservoir, further described in **Section 4.3.3**, there are no permitted WWTPs or industrial wastewater dischargers in the OTRW that received a WLA or are considered a source of TSS to the Otter Tail River (WID 09020103-504). Furthermore, there are no permitted dischargers upstream of Campbell Creek (WID 09020103-543).

Construction Stormwater

Construction stormwater can be a source of TSS due to runoff from disturbed and easily erodible soils during construction activities. The percent of developed land use in the watershed is less than 6% and construction permits require erosion control measures, so TSS from construction is considered, but is not considered to be a significant contributor of TSS to the impaired stream reaches within the OTRW. Furthermore, according to MPCA construction stormwater permit data, an average of just 0.3% of the entire OTRW area was covered under the applicable MPCA construction stormwater permit per year over the last five years (MPCA 2020m).

Industrial Stormwater

Industrial stormwater can contribute to the TSS load of waterbodies. While there are nine NPDES/SDS permitted industrial stormwater dischargers with a total of 35 discharge locations in the OTRW, industrial stormwater is not considered to be a significant source of TSS to the impaired stream reaches within the OTRW.

Municipal Stormwater Runoff

MS4 areas can contribute sediment from urban stormwater runoff systems. There are two MS4 areas within the OTRW but neither are upstream of the drainage area of Campbell Creek (WID 09020103-543). Both Detroit Lakes (MS400230) and Fergus Falls (MS400268) are upstream of the drainage area of the Otter Tail River (WID 09020103-504). However, due to the boundary condition created by the Orwell Reservoir mentioned above and further described in **Section 4.3.3,** these MS4 areas are not considered to be a source of TSS to the impaired stream reaches within the OTRW.

Animal Feedlots

Animal feedlots can be a source of sediment to surface and groundwater through runoff from open feedlots and manure storage areas. Regulations regarding manure stockpiling or liquid manure storage areas on site decrease the likelihood of a direct release of manure, and associated sediment, to waterbodies. Furthermore, all NPDES-permitted CAFOs must be designed to totally contain all manure, manure contaminated runoff, and process wastewater from precipitation events of less than a 25-year, 24-hour storm event. Permitted feedlots can be a source of sediment in ways similar to *E. coli*, which was further discussed in **Section 3.6.1.2**. Runoff from feedlots and manure storage areas, temporary stockpiling of manure, and manure application to agricultural fields are all assessed as manure application, a nonpermitted source of TSS, also similarly described in **Section 3.6.1.3** and as overland erosion, below.

3.6.2.2 Nonpermitted sources

Overland Erosion

Overland runoff of sediment is assessed to be the greatest contributor of TSS to waterbodies in the OTRW. High TSS can occur when heavy rains fall on unprotected soils, dislodging soil particles that are then transported with surface runoff to adjacent waterbodies. Losses are greatest during the spring, April through June, when vegetation is not yet actively growing, and rainfall is elevated. Ephemeral systems, streams, and gullies are highly susceptible to intermittent flows and have high erosion potential in agricultural systems. Farming practices can exacerbate erosion in sensitive areas if soil is unprotected from rain and there is insufficient buffering of stream channels. Other overland erosion sources include sediment from tile drainage, sheet and rill runoff from upland fields, and livestock pastures in riparian zones. **Figure 10** shows the average annual overland sediment erosion yields in the OTRW, based on the HSPF model results (1996 through 2014). For Campbell Creek, Campbell Lake to Floyd Lake (WID 09020103-543), the sediment yields range from 0.0001 (wetlands) to 0.24 tons/acre/yr (cropland). For Otter Tail River, JD 2 to Breckenridge Lake (WID 09020103-504), the sediment yields range from <0.0001 (wetlands) to 0.36 tons/acre/yr (cropland).

Streambank Erosion

Streambank erosion and scouring can contribute significant amounts of sediment to streams. Unstable stream banks are common in the OTRW. Stream bed and bank erosion is estimated based on the HSPF model results (1996 through 2014) to be a major source of the annual TSS load to the impaired streams and is attributed to poor riparian vegetation management near stream channels and altered hydrology throughout the region. Altered hydrology has increased stream flows due to lower water storage from tiling, altered evapotranspiration cycles, and decreased water residence time in the stream channel due to straightening. Managing water on- and below- fields, in addition to maintaining deep-rooted vegetation in the riparian zone, can stabilize soil and decrease sediment loading, lowering TSS in adjacent waterbodies. **Figure 11** shows the average annual in-channel sediment erosion rate in the reaches of the OTRW, based on HSPF model results (1996 through 2014). Each subwatershed in **Figure 11** represents the in-channel erosion rate in the modeled stream reach associated with the subwatershed. These erosion rates include streambank and bed erosion.

In-Channel Production

Algae can be a source of TSS in streams. Algal growth in waterbodies, commonly assessed as Chl-*a*, is naturally occurring, with highest growth commonly found in slow-moving streams or lakes with abundant nutrient supply. Algal growth can also be exacerbated by increased nutrients from anthropogenic sources.

Atmospheric Deposition

The atmosphere can contribute to stream TSS load. Average wind speeds in the OTRW are greater than five miles per hour and strong seasonal winds are capable of transporting sediment from fields. Dust from industrial and construction sites, bare soils, and developed areas can all contribute TSS to surface waters. Windblown sediment is a likely source of TSS within the OTRW, but is likely a small percentage of total TSS in impaired streams.

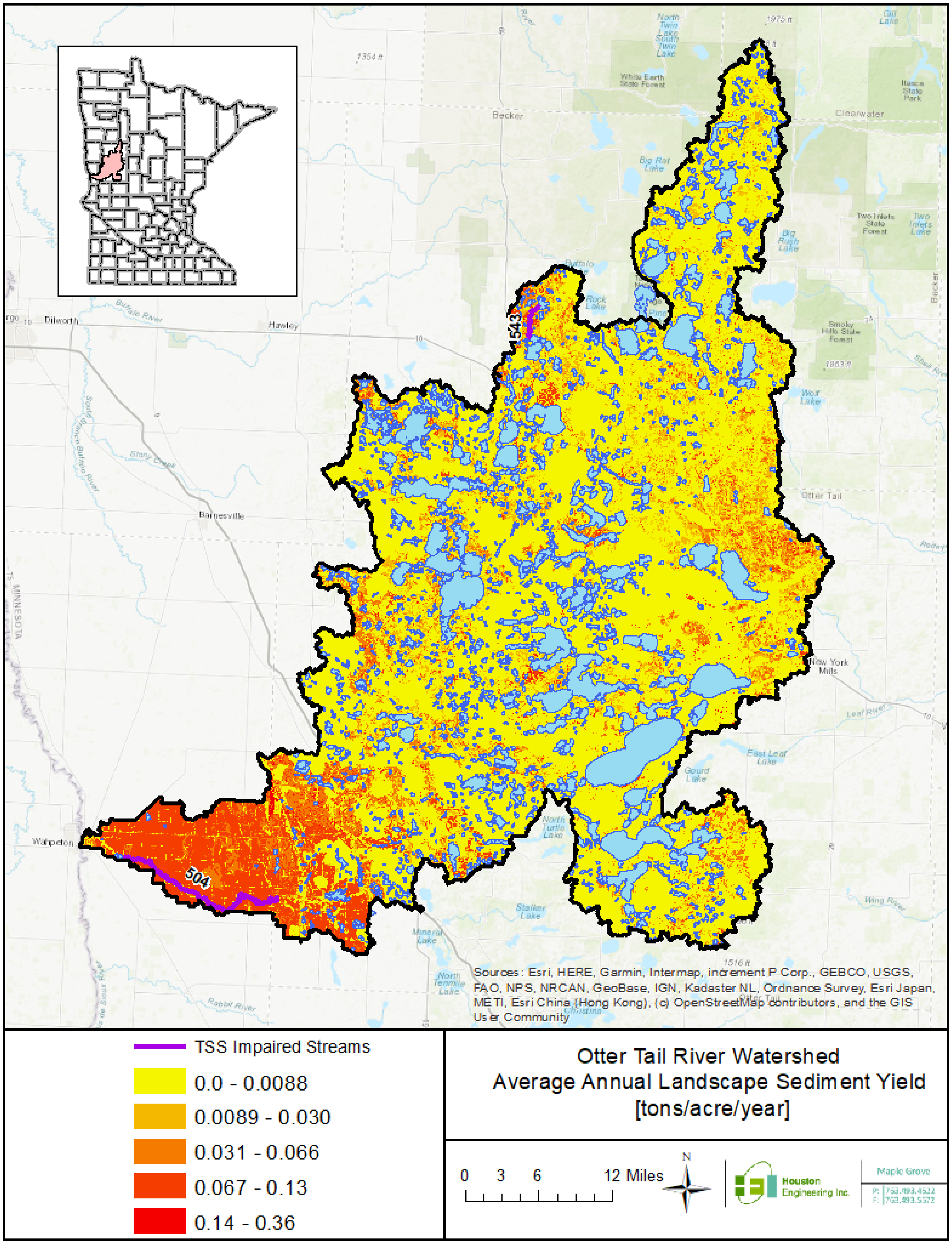

Figure 10. Average annual sediment yields (tons/acre/yr) from the landscape based on HSPF model results (1996-2014).

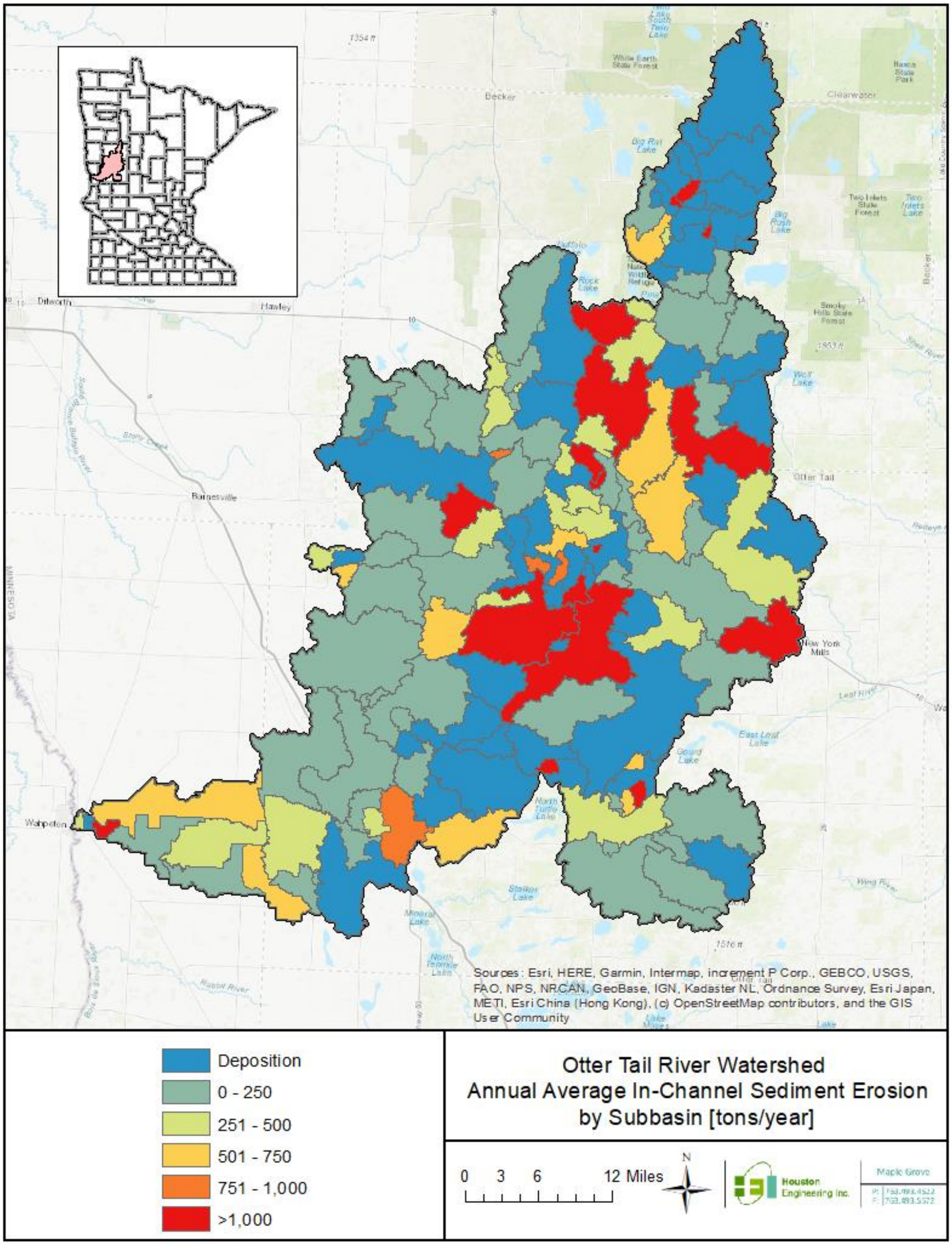

Figure 11. Average annual in-channel sediment erosion (tons/year) for stream reaches modeled in HSPF and based on HSPF model results (1996-2014).

3.6.3 Lake Nutrients

P and nitrogen (N) are the primary nutrients that, in excessive amounts, pollute lakes, streams, and wetlands. Nutrient availability in lakes in the OTRW is largely driven by the amount of P in lakes, versus N availability, therefore, the limiting nutrient controlling algal production and excessive nutrient impairments is usually P. P is an essential element for plant life, but when there is too much in the water, it can speed up eutrophication (a reduction in DO caused by increased mineral and organic nutrients). P is a common constituent of agricultural fertilizers, manure, and organic wastes in sewage and industrial effluent. Soil erosion is also a major contributor of P as P is often chemically bound to sediment particles. Significant amounts of streambank erosion can occur during flood events and can transport large amounts of P to streams and lakes.

For upland sources, sediment-bound P is the primary source of nutrient loading to lakes. Internal P, the P contained in lakebed sediment, can also be a large annual source of P to the water within a lake. Internal P cycles seasonally as the water in a lake turns over and P -rich water from the lake bottom mixes with surface waters. Bottom-feeding fish, such as carp, can also re-suspend the P in the water column through the disturbance of P -rich sediment. In shallow lakes that fully mix during seasonal turnover events and may continue to mix during the growing season, P from sediment becomes available to drive primary production. Internal loading and the effect of P made available, as well as other P sources, may vary yearly depending on environmental conditions and can be different in each lake.

Nutrient sources are described in more detail below by permitted and nonpermitted sources.

3.6.3.1 Permitted sources

Domestic and Industrial Wastewater

WWTPs can contribute P to lakes and streams. There are no domestic WWTPs or industrial wastewater dischargers within the drainage areas of impaired lakes covered by this TMDL report.

Construction Stormwater

Construction stormwater can be a source of P due to runoff with P bound to disturbed and easily erodible soils during construction activities. The percent of developed land use in the watershed is less than 6% and construction permits require erosion control measures, so P from construction is considered, but is not considered to be a significant contributor of P to impaired lakes in the OTRW. Furthermore, according to MPCA construction stormwater permit data, an average of just 0.3% of the entire OTRW area was covered under the applicable MPCA construction stormwater permit per year over the last five years (MPCA 2020m).

Industrial Stormwater

Industrial stormwater can be a source of P. A P containing material handled, used, processed, or generated that when exposed to stormwater may leak, leach, or decompose and be carried offsite can become a source of P if that material enters a waterbody. There are no NPDES/SDS permitted industrial stormwater sites in the drainage area of impaired lakes covered in this TMDL report.

Municipal Stormwater Runoff

P from sediment, grass clippings, leaves, fertilizers, and other P containing materials can be conveyed through stormwater pipe networks to surface waters. However, there are no permitted MS4s in the drainage area of the impaired lakes addressed in this TMDL report.

Animal Feedlots

Animal feedlots can be a source of P to surface and groundwater through runoff from open feedlots and manure storage areas. Regulations regarding manure stockpiling or liquid manure storage areas on site decrease the likelihood of a direct release of manure, and associated nutrients, to waterbodies. Furthermore, all NPDES-permitted CAFOs must be designed to totally contain all manure, manure contaminated runoff, and process wastewater from precipitation events of less than a 25-year, 24-hour storm event. Permitted feedlots can then be a source of nutrients in similar ways similar to *E. coli*, which was further discussed in **Section 3.6.1.2**. Runoff from feedlots and manure storage areas, temporary stockpiling of manure, and manure application to agricultural fields are all assessed as manure application, which would be a nonpermitted source of nutrients, also similarly described for *E. coli* in **Section 3.6.1.3** and further discussed below.

3.6.3.2 Nonpermitted sources

Upland Erosion

Soil erosion can be a source of nutrients, because P often binds to sediment particles and is transported downstream. Upland erosion includes overland erosion, open tile intakes, and tile lines. In addition to sediment, organic materials often contain P and, much like sediment, organic materials can be transported across the landscape with runoff. Overland erosion can occur by sheet, rill, or gully modes of sediment transport, which can convey P that is tightly bound to sediment to surface waters. Upon the formation of a gully, these areas are sensitive and highly susceptible to continued disturbance. In addition, P can be transported through tile lines in agriculture areas, although not as commonly as N. Protecting sensitive areas with deep-rooted vegetation that stabilizes soils can help mitigate P loss. Minimizing uncovered fields and maintaining natural, deep-rooted lakeshore trees and vegetation can also reduce the erosive power of heavy rain events.

According to HSPF modeling results (1996 through 2014), P loading to lakes from upland sources ranges from 0.005 lbs/acre/year for wetlands and water to 0.75 lbs/acre/year for cropland for the OTRW. **Figure 12** shows the modeled average annual P yields (lbs/acre/yr) from the landscape in the OTRW. Overland runoff coupled with a high percentage of straightened stream channels, agricultural land use, loss of wetlands and tiling – jointly indicating an altered hydrology – increases the conveyance of P loss from the landscape to waterbodies once mobilized from soils. Crop surface runoff accounts for 38% of TP loading in the basin. Crop tiling accounts for 23% of TP.

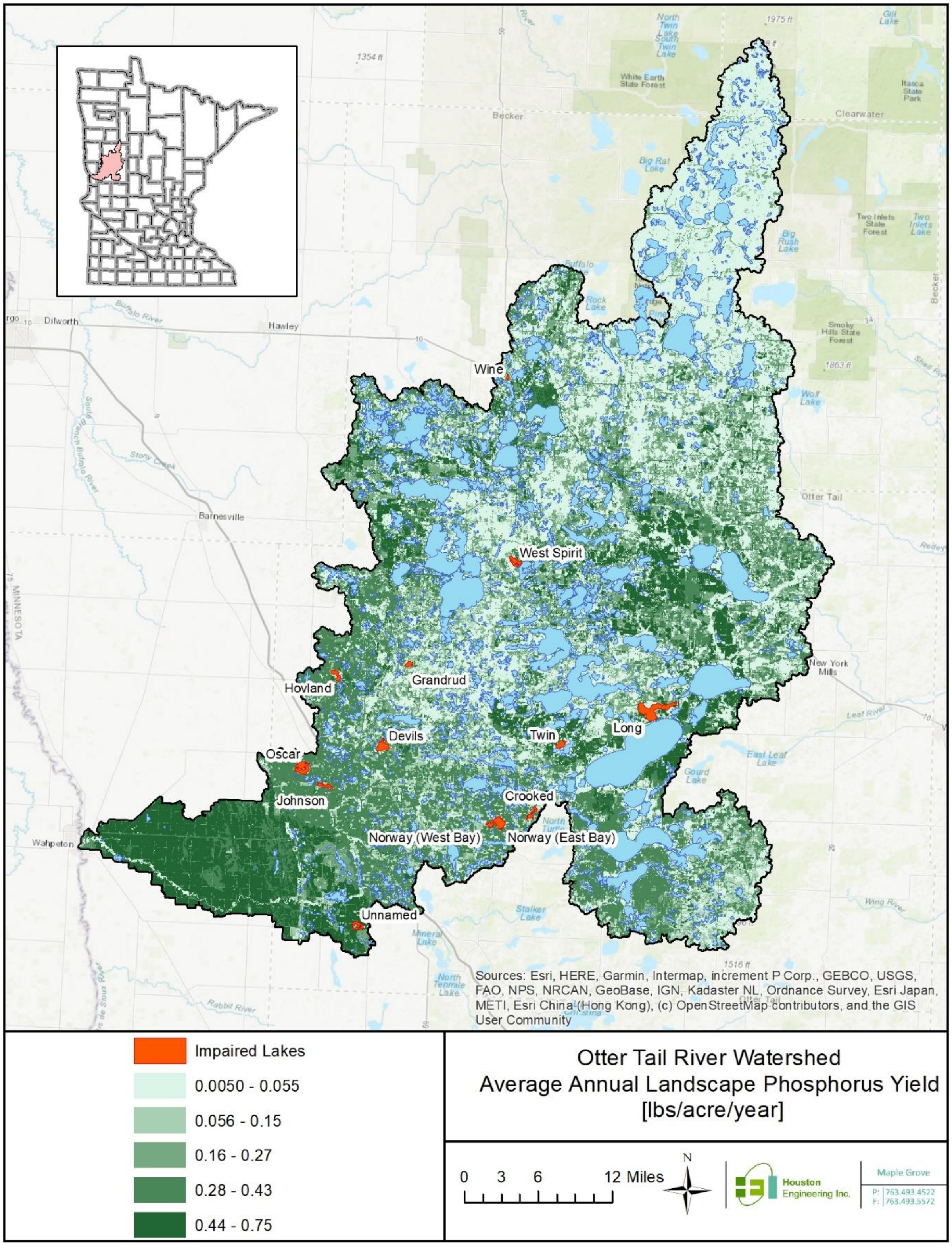

Figure 12. Average annual phosphorus yields (lbs/acre/yr) from the landscape based on HSPF model results (1996-2014).

Stream Bank Erosion

Like upland erosion, P can be bound to sediment in streambanks and can become a source to downstream waterbodies when that sediment is carried downstream. During large precipitation events or during spring snow melt, streams can convey water at high velocity with significant stream energy. High stream power values commonly observed in the OTRW may exceed the stress stream banks can withstand (MPCA 2019b). This leads to bank failure and streambank erosion, causing sediment and sediment-bound P to be transported downstream. The removal of natural vegetation can exacerbate streambank erosion along a channel. In addition, alterations to the stream reaches, e.g. channel widening and channel straightening, further increase stream energy and likelihood of streambank erosion. Near streambank and channel erosion is likely a minor source, due to the high proportion of direct drainage to the impaired lakes.

Manure Application and Nonpermitted Animal Feedlots

Manure is a by-product of animal production and often has a high P content. Animal feeding operations and feedlots generally create large quantities of manure that is usually stockpiled or held in liquid manure storage basins and then spread over agricultural fields to help fertilize the soil. The timing of manure spreading, as well as the application rate and method, can decrease the likelihood of nutrient loading to nearby waterbodies. Both liquid and solid manure are typically surface applied with varying methods of incorporation at the time of application. Oftentimes, liquid manure is directly injected into the soil during application. Solid manure is, at times, applied to frozen or snow-covered soils without incorporation resulting in an increased potential to runoff to nearby lakes and streams. High intensity precipitation events and snowmelt in the spring can also cause erosion of both the soil and manure that is applied onto the soil, leading to high P loads making their way to streams and lakes. Deferring manure application until snow has melted and soils have thawed decreases overland runoff associated with large precipitation events. Injecting or incorporating manure is a preferred BMP to reduce the runoff of waste and associated nutrients as incorporating manure into the soil reduces the risk of surface runoff associated with large precipitation events.

P is commonly applied in excess of the uptake needs of the crop. This excessive application can be compounded since the manure application rate is often based on the N uptake needs of the crop, leading to excessive P application to a field. If this excessive P is then exposed to precipitation events or snowmelt, it is then susceptible to runoff to nearby lakes and streams instead of being utilized by a growing crop.

Animal waste, and the associated nutrients, from nonpermitted feedlots and manure application can be delivered to surface waters from failure of manure storage areas, runoff from the feedlot facilities or manure stockpiles, or runoff from nearby fields where the manure is land applied. While a full accounting of the fate and transport of manure was not conducted for this project, a large portion of the manure is ultimately applied to the land surface and, therefore, this source is of possible concern in the OTRW. Minn. R. 7020.2225 contains several requirements for land application of manure; however, there are no explicit requirements for nutrient removal prior to land application.

Pasture

Livestock can contribute to nutrient loading to waterbodies from poorly managed pasture lands that are overgrazed or through the direct access of livestock to surface waters. Poorly maintained pasture can have significant overland surface flow during heavy precipitation events resulting in manure transport from the pasture, especially where feeding structures or watering devices are located adjacent to riparian areas and waterbodies. Livestock with direct access to streams and lakes can defecate directly into the waterbody resulting in direct nutrient contamination. While a full accounting of livestock access to waterbodies or runoff from pastures was not conducted for this project, it is assumed that livestock grazing and pastures exist throughout the watershed. Therefore, this source is of possible concern in the OTRW.

Internal Loading

Internal loading can be a significant source of nutrients in lakes, especially in shallow lakes and if the lake has a long history of excessive P. Lakebed sediments can be high P contributors as organic material and sediment fall out of the water column, settling on the bottom of a lake. There are multiple ways P can be released back into the water column from sediment (i.e., internal loading):

- *Chemical release from sediment:* During periods of low oxygen concentrations (i.e., anoxic conditions with DO concentrations < 2.0 mg/L) or high pH (pH > 9) in the hypolimnion (lake bottom), P is released from the water-sediment interface. During the summer, lakes can stratify due to temperature and density difference in the water column. When the lake loses its stratification, the released P mixes throughout the water column, typically in the fall (dimictic lakes). This tends to occur more in deep lakes than shallow lakes. For shallow lakes, periods of anoxic conditions can last for short periods of time and the water column will mix frequently (polymictic lakes). The impaired lakes addressed in this TMDL report are shallow and most likely polymictic lakes (multiple mixing events throughout the year).
- *Fish disturbances of the lake sediment:* Bottom-feeding fish, such as bullhead and carp, forage in and disrupt lake sediments. This physical disturbance can release P into the water column. Fisheries data available on the DNR's LakeFinder website currently only has data for one of the impaired lakes addressed in this TMDL report, Norway Lake (East Bay), and indicates that yellow bullheads and white suckers are present. It is assumed based on local knowledge that similar fish may exist in all the impaired lakes addressed in this TMDL report.
- *Physical disturbances of the lake sediment.* Wave action from wind energy and motorized boats in shallow depths can mix the water column and disturb bottom sediments, which leads to P release.

Some amount of internal loading is implicit in the BATHTUB model's equations, but many lakes needed an explicit "additional" internal load to reach observed P concentrations. To estimate the "additional" internal loading for the impaired lakes, an additional P load was added to the lake P budgets to calibrate the BATHTUB models (see **Section 4.4.1**); this load was attributed to internal loading and/or other unknown sources that were not quantified with currently available data, such as additional, unidentified loading from surface loads, animal feedlot runoff, and/or SSTS. Specific internal loading rates are provided in **Section 4.4.1**, along with the methodology for determining internal loading rates.

Urban/Developed Runoff

P from sediment, grass clippings, leaves, fertilizers, and other P containing materials can be transported to surface waters through surface runoff from developed areas surrounding the lakeshore and can be a significant source of P. According to the HSPF model, the P yields from developed areas to OTRW lakes range from approximately 0.35 lbs/acre/year for roads and open spaces to 1.48 lbs/acre/year for medium and high density areas.

Subsurface Sewage Treatment System

Nutrients from SSTSs can be a source of P in ways similar to *E. coli*, as discussed in **Section 3.6.1.3**. Failing SSTSs near waterbodies with an insufficient dry zone between the drain field and bedrock or saturated zone, or improperly designed SSTSs (i.e., ITPHS), can result in the transfer of P to groundwater and surface waters. The variable number of noncompliant ITPHS SSTSs in the OTRW, modeled to be between 0.71 and 4.67 systems per 1,000 acres based on data provided by the counties with significant contributing areas to the OTRW, can contribute to increased P loads of surface waters. However, developed land cover in the drainage areas of the impaired lakes ranges from as low as 1.5% to a high of 12%, and the immediate lakeshores of all but one of the impaired lakes are relatively undeveloped. Therefore, this source is of possible yet less significant concern in the OTRW and is accounted for with all other NPS in the TMDL LAs. Counties in the watershed continue to improve SSTS assessment and conduct outreach to the public regarding system maintenance and replacing noncompliant systems, as further discussed in **Section 6.2.1**.

Atmospheric Deposition

Atmospheric deposition to the surface of lakes can be a source of P, including pollen, soil (aeolian particulates), oil, coal particulate matter, and fertilizers. Regional P loading for the region is modeled to be 0.261 kg/ha/year or 26.1 kg/km^2/year (Barr 2007).

3.6.3.3 Summary of Sources by Lake

The relative magnitude of the sources of P to impaired lakes addressed in this TMDL report are shown in **Table 13**. The values shown in **Table 13** are based on the HSPF model (1996 through 2014) and the BATHTUB lake modeling (atmospheric deposition and internal loading) developed for this TMDL report. The percentages are the percent of the average annual existing P load (lbs/yr) stemming from the listed source. Overall, internal loading is the largest source of P for the impaired lakes, followed by runoff from cropland, grassland/pasture, and impervious/developed areas. In some lakes, atmospheric deposition is a substantial source (greater than 10%). These lakes generally have a small lakeshed area-to-surface area ratio, meaning the lake itself is a substantial portion of the lakeshed (**see Table 5**).

Table 13. Relative magnitude of phosphorus (P) sources to impaired lakes addressed in this TMDL report based on HSPF and BATHTUB modeling (1996 – 2014).

Lake Name	WID	Existing P Load [lbs/yr]	Atmospheric Deposition	Impervious/ Developed	Cropland	Grassland/ Pasture	Forest	Wetlands/ Water	Internal Load
Wine	03-0398-00	78	9.29%	13.69%	13.35%	9.05%	1.92%	0.08%	52.63%
Long	56-0210-00	4,294	5.92%	0.89%	4.12%	2.04%	0.59%	0.02%	86.42%
Crooked	56-0458-00	468	6.56%	6.14%	29.09%	8.11%	1.50%	0.11%	48.48%
West Spirit	56-0502-00	426	14.27%	1.76%	2.87%	3.45%	2.05%	0.00%	75.60%
Norway (East Bay)	56-0569-01	1,507	4.85%	0.41%	6.43%	0.85%	0.20%	0.06%	87.20%
Norway (West Bay)	56-0569-02	1,229	1.76%	3.59%	23.04%	5.90%	0.46%	0.11%	65.13%
Unnamed	56-0791-00	1,069	3.05%	1.01%	19.88%	0.32%	0.01%	0.05%	75.67%
Devils	56-0882-00	1,148	6.25%	2.07%	14.46%	6.83%	0.61%	0.08%	69.70%
Grandrud	56-0907-00	210	12.56%	4.95%	13.10%	10.81%	3.32%	0.11%	55.16%
Johnson	56-0979-00	333	10.76%	8.63%	76.52%	3.76%	0.24%	0.09%	0.00%
Oscar	56-0982-00	3,487	2.25%	7.20%	47.88%	3.58%	0.90%	0.26%	37.93%
Hovland	56-1014-00	2,587	1.63%	1.31%	16.68%	0.82%	0.34%	0.06%	79.17%
Twin	56-1525-00	806	5.22%	1.56%	15.88%	1.39%	0.45%	0.12%	75.36%

4. TMDL development

A TMDL represents the maximum mass of a pollutant that can be assimilated by a receiving waterbody without causing an impairment in that receiving waterbody. TMDLs are developed based on the following equation:

$$TMDL = LC = \sum WLA + \sum LA + MOS$$

Where:

LC = loading capacity, or the greatest amount of a pollutant a waterbody can receive and still meet water quality standards (see **Section 4.2.1, 4.3.1, and 4.4.1**);

WLA = wasteload allocation, or the portion of the loading capacity allocated to existing or future permitted point sources (see **Section 4.2.3, 4.3.3, and 4.4.3**);

LA = load allocation, or the portion of the loading capacity allocated for existing or future nonpermitted or NPS, including natural background (see **Section 4.2.2, 4.3.2, and 4.4.2**);

MOS = margin of safety, or accounting for any uncertainty associated with attaining the water quality standard. The MOS may be explicitly stated as an added, separate quantity in the TMDL calculation or may be implicit, as in a conservative assumption (EPA 2007) (see **Section 4.2.5, 4.3.4, and 4.4.4**).

Per Code of Federal Regulations (40 CFR 130.2(1)), TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For this TMDL report, the TMDLs, allocations and margins of safety are expressed in mass/day. Each component of the TMDL is discussed in greater detail below.

4.1 Natural background and Data Sources

4.1.1 Natural background consideration

Natural background conditions refer to inputs that would be expected under natural, undisturbed conditions. Natural background sources can include inputs from natural geologic processes such as soil loss from upland erosion and stream development, atmospheric deposition, and loading from forested land, wildlife, etc. For each impairment, natural background levels are implicitly incorporated in the water quality standards used by the MPCA to determine/assess impairment, and therefore natural background is accounted for and addressed through the MPCA's waterbody assessment process. Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion of this study. These source assessment exercises indicate natural background inputs in the OTRW are generally low compared to livestock, cropland, streambank, WWTPs, failing SSTSs, and other anthropogenic sources.

Based on the MPCA's waterbody assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest that natural background sources are a major driver of any of the impairments and/or affect the waterbodies' ability to meet state water quality standards. For all impairments addressed in this TMDL report, natural background sources are implicitly included in the LA portion of the TMDL allocation tables and TMDL reductions should focus on the major anthropogenic sources identified in the source assessment[3].

4.1.2 Data Sources

4.1.2.1 Hydrologic Simulation Program-Fortran

The HSPF model is a comprehensive package for simulation of watershed hydrology, sediment transportation, and water quality for conventional and toxic organic pollutants. HSPF incorporates the watershed-scale Agricultural Runoff Model (ARM) and NPS models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. It is a comprehensive model of watershed hydrology and water quality that allows the integrated simulation of point sources, land and soil contaminant runoff processes, along with in-stream hydraulic and sediment-chemical interactions. The result of this simulation is a time history of the runoff flow rate, sediment load, and nutrient and pesticide concentrations, along with a time history of water quantity and quality at the outlet of any subwatershed.

The HSPF model used for this TMDL was developed in 2017 for the Otter Tail River Basin (Tetra Tech 2017). The HSPF model predicts the range of flows that have historically occurred in the modeled area and the load contributions from a variety of point and nonpoint sources in a watershed. The model simulates hydrology and water quality for the period 1995 through 2014. Modeled flows from the HSPF model were used to develop the LDCs for streams, and runoff and P loads were used to develop the lake models.

4.1.2.2 Environmental Quality Information Systems

As discussed in **Section 3.5**, the MPCA uses a system called EQuIS to store water quality data from more than 17,000 sampling locations across the state (MPCA 2020b). All discrete water quality sampling data utilized for assessments and data analysis for this TMDL report are stored in this database and are publically accessible through the MPCA's *Environmental Data Access* (EDA) website (MPCA 2020c). The EQuIS locations and water quality data used in this TMDL report are provided in **Table 8** (*E. coli*), **Table 9** (TSS), and **Table 10** (lake nutrients), and monitoring locations are shown in **Figure 8** and **Appendix 4.**

4.2 *Escherichia coli*

4.2.1 Loading capacity methodology

The LC is the greatest amount of a pollutant a waterbody can receive and still meet the water quality standard. The loading capacities for impaired stream reaches in the OTRW were determined using the LDC approach. An LDC is developed by combining the (simulated or observed) river/stream flow at the downstream end of the WID with the observed/measured *E. coli* data available within the segment. Methods detailed in the EPA document An Approach for Using Load Duration Curves in the Development of TMDLs (EPA 2007) were used in creating the curves.

A system's water quality often varies based on flow regime, with elevated pollutant loadings sometimes occurring more frequently under one regime or another. Loading dynamics during certain flow

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[3] Reference found on the MPCA website: [Little Rock Creek TMDL Court of Appeals Decision](); Filed November 28, 2016

conditions can be indicative of the type of pollutant source causing an exceedance (e.g., point sources contributing more loading under low flow conditions). The LDC approach identifies these flow regimes and presents the observed and "allowable" loading along with the necessary load reductions within each regime. To represent different types of flow events, and pollutant loading during these events, five flow regimes were identified based on percent exceedance: Very High Flow (0% to 10%), High Flow (10% to 40%), Mid-Range Flow (40% to 60%), Low Flow (60% to 90%), and Very Low Flow (90% to 100%).

Benefits of LDC analysis include: (1) the loading capacities are calculated for multiple flow regimes, not just a single point; (2) use of the method helps identify specific flow regimes and hydrologic processes/patterns where loading may be a concern; and (3) ensuring that the applicable water quality standards are protective across all flow regimes. Some limitations with the LDC approach exist: (1) there is limited ability to track individual loadings or relative source contributions and (2) the method is only appropriate when a correlation between flow and water quality exists, and flow is the driving force behind pollutant delivery mechanics.

The LDC method is based on an analysis that encompasses the cumulative frequency of historical flow data over a specified period. Because this method uses a long-term record of daily flow volumes, virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the *E. coli* TMDL equation tables of this report (**Table 20** through **Table 27**), only five points on the entire LC curve are depicted (the midpoints of the designated flow zones). However, it should be understood that the entire curve represents the TMDL and it is what the EPA ultimately approves.

The LC was calculated using both standards: the geometric mean standard of 126 organisms/100 mL and the standard that requires that less than 10% of applicable samples measure above 1260 organisms/100 mL. The water quality standards for *E. coli* apply during April through October. Loads are calculated as organisms per day and reported as billions of organisms/day.

Table 14. Converting flow and concentration into bacterial load.

Load (org/day) = *E. coli* Standard (organisms/100mL) * Flow (cfs)[1] * Factor			
Multiply **Flow (cfs)** by **28.316** to convert	ft^3 per second (cfs)	→	Liters per second
Multiply by **1000** to convert	Liters per second	→	Milliliters per second
Divide by **100** to convert	Milliliters per second	→	Organisms/second
Multiply by **86,400** to convert	Organisms per second	→	Organisms/day

[1]cfs: cubic feet per second

It should be noted that some observed *E. coli* data were collected outside (beyond 2014) the period of available flows (2005 through 2014). Therefore, existing conditions could not be estimated without flow transfer to determine flow conditions on the days when samples were collected. A flow transfer was developed using the closest USGS gage (USGS# 05460000) with a sufficient data record to complete the flow transfer. The flow transfer was conducted by developing a linear regression equation **(Table 15)** comparing the distributions of flows at the USGS gaging station and the simulated flows in the impaired reach for the LDC period (2005 through 2014). Once the regression equation was developed, the percent exceedance of the observed data was calculated and transformed using the regression equation. Then the absolute flow was estimated by finding the flow of the transfer flow exceedance using the simulated flow distribution (from HSPF). Flow transfer equations were not developed for WID

09020301-526 and 09020301-757; they did not have observed water quality data after 2014 (the range of available flows) and, therefore, did not need them.

Table 15. Flow transfer equations used to develop existing conditions in *E. coli* TMDLs.

WID (Stream Name)	HSPF RCHRES ID	Transfer Flow Site (USGS ID)	Transfer Equation[1]	R^2
09020301-574 (Otter Tail R)	300	USGS 05046000	$\%Model_I = 0.897436*\%Obs_{I-5} + 0.049181$	0.802
09020301-761 (Unnamed Cr)	102	USGS 05046000	$\%Model_I = 0.521897*\%Obs_{I-7} + 0.236575$	0.273
09020301-764 (JD 2)	108	USGS 05046000	$\%Model_I = 0.601469*\%Obs_{I-7} + 0.19698$	0.362
09020301-768 (Pelican R)	200	USGS 05046000	$\%Model_I = 0.825539*\%Obs_{I-7} + 0.084795$	0.680
09020301-770 (Toad R)	507	USGS 05046000	$\%Model_I = 0.617835*\%Obs_{I-7} + 0.188402$	0.383
09020301-772 (Pelican R)	230	USGS 05046000	$\%Model_I = 0.640607*\%Obs_{I-7} + 0.177045$	0.411

[1]$\%Model_I$ = the percent exceedance of the model flow, and $\%Obs_I$ = the percent exceedance of the observed flow.

4.2.2 Load allocation methodology

LAs represent the portion of the LC designated for nonpermitted or NPS of *E. coli*. The LA is the remaining load once the WLA and MOS are determined and subtracted from the LC. The LA includes all sources of *E. coli* that do not require NPDES/SDS permit coverage, including unregulated watershed runoff and natural background conditions as discussed in **Section 4.1.1**. NPS of *E. coli*, including natural background, were previously discussed in **Section 3.6.1.3.**

4.2.3 Wasteload allocation methodology

WLAs are developed for any permitted discharge in the drainage area of an impaired reach. These are discharges that require an NPDES/SDS permit, and typically include domestic WWTPs, permitted MS4s, industrial wastewater or stormwater discharges, construction stormwater, and permitted feedlots. All WLAs developed in this TMDL are equivalent to or consistent with current permitted effluent limits where they apply. Therefore, no new or additional reductions are necessary at any permitted facilities with regulated effluent limits, such as WWTPs. However, this may not apply to permittees with no specifically permitted effluent limits, such as permitted MS4s.

Boundary Conditions

Boundary conditions were applied to two reaches impaired due to *E. coli*, the Otter Tail River, Unnamed Lake (56-0821-00) to Pelican River (WID 09020103-574) and the Pelican River, Reed Creek to Otter Tail River (WID 09020103-768). The boundary conditions were applied to represent the positive impact of upstream reaches that have been assessed to meet *E. coli* water quality standards and support aquatic recreation, as well as the numerous in-line lakes that are upstream in each river and that help to minimize the impacts of the upstream watershed on the impaired reaches. Additionally, the monitoring locations where the applicable *E. coli* data was collected and used to develop these TMDLs are located at the downstream end of the impaired reaches (see **Section 3.5)**. Therefore, the lakes and river reaches upstream of the boundary condition areas are expected to assimilate the *E. coli* from the upstream watershed, and the impairments are expected to be caused within the contributing boundary condition areas. The boundary conditions were then applied to ensure that the permitted dischargers and NPS located within the boundary condition areas and that may contribute to the impairments are included in the appropriate allocations, and that the permitted dischargers and NPS within the total drainage areas but upstream of the boundary condition areas, and that do not likely contribute to the impairments, are allocated in the upstream boundary condition load.

For the Otter Tail River (WID 09020103-574), the upstream reach from River Diversion to Unnamed Lake (56-1203-00) (WID 09020103-774) was assessed to meet the applicable *E. coli* water quality standards and support aquatic recreation (MPCA 2019a). According to the Otter Tail River Basin HSPF model (Tetra Tech 2017) and as discussed in **Section 4.2.1**, simulated flow data for the applied boundary condition area are available for the outlet of Unnamed Lake (56-1203-00) but not for the inlet of Unnamed Lake (56-1203-00) at the downstream end of WID 09020103-774. Therefore, the applied boundary condition assumes that the outflow of Unnamed Lake (56-1203-00) also meets applicable *E. coli* standards, and the boundary condition area starts at the outlet of Unnamed Lake (56-1203-00) and goes to the outlet of the impaired reach, Otter Tail River, Unnamed Lake (56-0821-00) to Pelican River (WID 09020103-574). The total boundary condition area is 9.462 square miles, while the total contributing area within the boundary condition area is 3.582 square miles.

For the Pelican River (WID 09020103-768), the upstream reach from Lake Lizzie to Reed Creek (WID 09020103-767) was assessed to meet the applicable *E. coli* water quality standards and support aquatic recreation, while the adjacent Reed Creek, from Reed Lake to Pelican River (WID 09020103-653) has no available *E. coli* data and was not assessed (MPCA 2019a). Furthermore, the simulated flow data from the Otter Tail River Basin HSPF model (Tetra Tech 2017) at the start of the impaired reach (WID 09020103-768) includes outflows from both the upstream reach (WID 09020103-767) and Reed Creek (WID 09020103-653). Therefore, the applied boundary condition assumes that the flow at the start of the impaired reach (WID 09020103-768) will continue to meet applicable *E. coli* standards, and the boundary condition area starts at the upstream end and ends at the outlet of the impaired reach, Pelican River, Reed Creek to Otter Tail River (WID 09020103-768). The total boundary condition area is 34.805 square miles, while the total contributing area within the boundary condition area is 23.566 square miles.

The contributing boundary condition areas are shown in **Figure 13** and in the individual subwatershed maps in **Appendix 4**. Boundary conditions were not applied to the remaining reaches that are impaired due to *E. coli,* since none of the remaining impaired reaches have upstream reaches that were assessed to be meeting applicable *E. coli* water quality standards and supporting aquatic recreation.

Domestic and Industrial Wastewater

WLAs for domestic WWTPs are based on the reported maximum allowable discharge and the permitted concentration limits. For controlled systems, maximum daily flow is based on a six-inch per day discharge from the facility's secondary pond(s). The conversion for WWTPs from concentrations to loads is shown in **Table 16**. The estimated maximum flow rate for controlled systems is shown in **Table 17**. The WWTPs, permit numbers, permitted flows, and WLAs are provide in **Table 18.**

Industrial wastewater dischargers are not considered to be a source of *E. coli* to impaired streams in the OTRW and as such receive no WLA.

Table 16. Converting flow and concentrations into bacterial loads for wasteload allocations.

Wasteload (org/day) = *E. coli* Limit (126 organisms/100mL) * Flow (mgd)[1] * Factor			
Multiply *E. coli* limit (**126** organisms/100ml) by **10** to convert	Organisms per 100 mL	→	Organisms per Liter
Multiply by **3.785** to convert	Organisms per Liter	→	Organisms per gallon
Multiply by **1,000,000** to convert	Organisms per gallon	→	Organisms per million gallons

[1]mgd: million gallons per day

Table 17. Secondary pond size and maximum daily discharge for controlled WWTP systems.

Facility Name	Secondary Pond Acreage (ac)	Gallons per acre-inch	Volume of 6" discharge (mgd)
Elizabeth WWTP	1.77	27,154	0.288

Table 18. *E. coli* WLAs for NPDES/SDS permits in impaired reaches of the OTRW.

Facility Name	Permit No.	Surface Discharge Station	Permit Limit (as *E. coli*)		Max Daily Flow (mgd)	*E. coli* WLAs (billion org/day)	Flow Type
			org/100 mL	org/100 mL			
Elizabeth WWTP	MNG585012	SD 001	126	1260	0.288[1]	1.375	Controlled
Fergus Falls WWTP	MN0050628	SD 001	126	1260	2.81	13.401	Continuous

[1]Based on 6" daily discharge of secondary pond.

Straight Pipe Septic Systems

Straight pipe septic systems are illegal and unpermitted, and as such, receive no WLA. Failing SSTS and ITPHS systems are assessed as nonpermitted sources and are accounted for in the LA portion of the TMDL.

Construction and Industrial Permits

WLAs for sites covered under the Construction Stormwater General Permit (NPDES/SDS permit# MNR100001) were not developed for *E. coli*, since *E. coli* is not a typical pollutant associated with construction sites. Industrial stormwater sites receive a WLA only if fecal bacteria or *E. coli* is part of the benchmark monitoring for a permitted industrial site in the drainage area of an impaired waterbody. There are no fecal bacteria or *E. coli* benchmarks associated with the Industrial Stormwater General Permits (NPDES/SDS permit# MNR050000 or MNG490000), and also no Industrial Stormwater Individual Permits with *E. coli* benchmarks in the OTRW impaired watersheds. Therefore, no industrial stormwater *E. coli* WLAs were assigned.

Municipal Separate Storm Sewer System

The WLA for communities subjected to MS4 NPDES/SDS stormwater permit requirements is taken as a percentage of the LC based on the percentage of the contributing drainage area for the impaired reach that the MS4 permit area covers. Non-contributing areas, or portions of the MS4 area identified in the Otter Tail River Basin HSPF model (Tetra Tech 2017) as not contributing to OTRW stream flows, were excluded. There are two MS4 areas within the OTRW and both are partially within the contributing drainage areas of impaired stream reaches addressed in this TMDL report, Detroit Lakes (MS400230) and Fergus Falls (MS400268). The Detroit Lakes MS4's total area covers 15.17 square miles and the

Fergus Falls MS4's total area covers 15.26 square miles. Contributing drainage areas of three *E. coli*-impaired reaches each include portions of one MS4 area. For the Otter Tail River, Unnamed Lake (56-0821-00) to Pelican River (WID 09020103-574) and the Pelican River, Reed Creek to Otter Tail River (WID 09020103-768), the boundary condition was applied. Therefore, the MS4 WLA for these impaired reaches is taken as the percentage of the LC minus the boundary condition load. No boundary condition was applied for the Pelican River, Highway 10 to Detroit Lake (WID 09020103-772). As described in **Section 3.6.1.2,** *E. coli* loading from the Fergus Falls MS4 area currently does not need to be reduced, but should not be increased, in order to meet the WLA for the Pelican River, Reed Creek to Otter Tail River (WID 09020103-768). **Table 19** provides the contributing drainage area of the impaired reaches, the MS4 area within the contributing drainage area, the percentage of the contributing drainage area covered by the MS4 area, and the percentage of the LC used as the WLA for the MS4. Locations of the MS4 areas relative to the impaired streams' total drainage areas are shown in **Figure 6** and **Appendix 4**. **Figure 13** shows where the relevant impaired streams' contributing drainage areas and boundary condition areas are located in relation to the MS4 boundaries**.**

Table 19. Percentage of contributing drainage areas covered by MS4 permits in *E. coli* impaired streams.

Impaired WID	Stream Name	Contributing Drainage Area [sq. mi.]	MS4	Contributing MS4 Area [sq. mi.]	Percentage of Contributing Drainage Area	Percentage of Loading Capacity
09020301-574	Otter Tail R	3.582[1]	Fergus Falls	2.613	73.0%	73.0%[3]
09020301-768	Pelican R	23.566[1]	Fergus Falls	0.567	2.41%	2.41%[3]
09020301-772	Pelican R	41.176[2]	Detroit Lakes	2.063	5.01%	5.01%[4]

[1]Total contributing drainage area within the applied boundary condition area, excluding any non-contributing areas.

[2]Total contributing drainage area, excluding any non-contributing areas.

[3]The percentage of the loading capacity is taken as the percentage of the remaining load (loading capacity minus the boundary condition load).

[4]No boundary condition was applied. The percentage of the loading capacity is based on the percentage of the contributing drainage area within the Detroit Lakes MS4 boundaries.

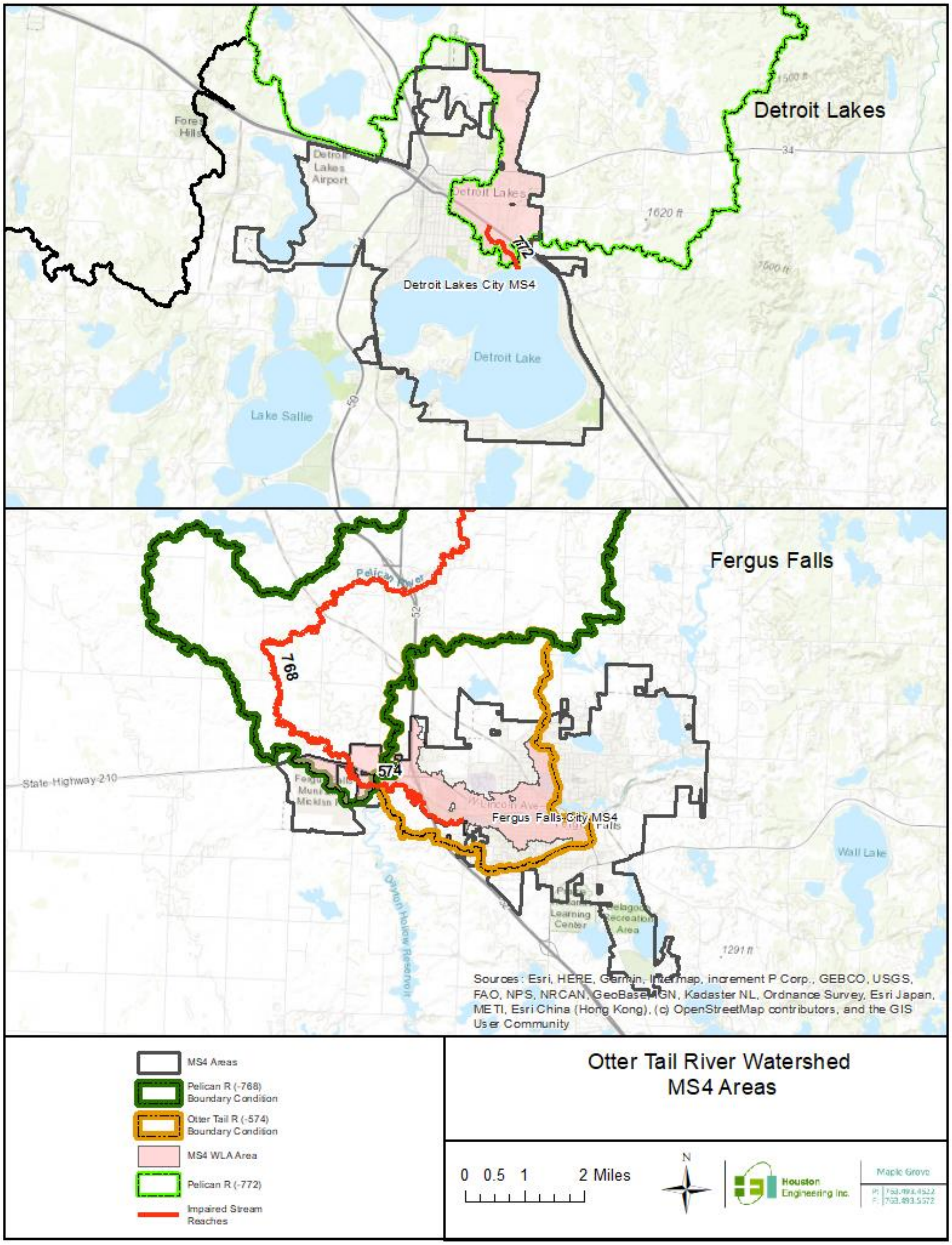


Figure 13. Contributing drainage areas of the MS4 areas in the OTRW.

Animal Feedlots

NPDES and SDS permitted feedlot facilities and CAFOs not requiring permits are assigned a zero WLA and are not included in the TMDL tables in **Section 4.2.7**. Although all 11 CAFOs in the OTRW are upstream of at least one *E. coli*-impaired stream reach, this is consistent with the conditions of the permits and the design and operation standards and requirements for CAFOs in Minnesota, which allow no pollutant discharge from the livestock housing facilities and associated manure storage areas. Discharge of *E. coli*-laden manure from non-CAFO feedlots and fields where manure has been stockpiled or land-applied may occur during runoff events, but those discharges are covered within the LA portion of the TMDL and do not require an additional WLA.

4.2.4 WLA and LA expressed as an equation

A special case occurs for the Otter Tail River, Unnamed Lake (56-0821-00) to Pelican River (WID 09020301-574). The combined WWTP permitted design flow and estimated MS4 runoff exceed the boundary condition area's remaining load for all flow regime conditions except for the very high flow condition. This translates to these permitted sources appearing to exceed the remaining load during these flow regimes. In reality, this will never occur as the discharge from the WWTP and the runoff from the MS4 area are a part of the streamflow and can never exceed the total streamflow or remaining load. To account for this unique situation, the WLA and LA are expressed as an equation rather than an absolute number. The equation is:

Allocation = Point Source (WWTP) Discharge or Runoff (MS4 or NPS) X Water Quality Standard Concentration

Consistent units are used to obtain the load. This assigns a concentration-based limit to the WLA and LA for these flow rates.

4.2.5 Margin of safety

The purpose of the MOS is to account for uncertainty with the allocations resulting in attaining water quality standards. Uncertainty can be associated with data collection, lab analysis, data analysis, modeling error, and implementation activities. An explicit 10% of the LC MOS was applied to each flow regime for all LDCs developed for this TMDL. The LDC approach minimizes a great deal of uncertainty. The explicit 10% MOS accounts for:

- Uncertainty in the simulated flow data from the HSPF model;
- Uncertainty in the observed water quality data;
- Uncertainty with the observed watershed quality data representing the water quality conditions in the stream; and
- Uncertainty with regrowth, die-off, and natural background levels of *E. coli*.

The majority of the MOS is apportioned to uncertainty related to the HSPF model, over the other sources of uncertainty. The hydrologic calibration statistics for the HSPF model at the Otter Tail River below Orwell Dam near Fergus Falls, Minnesota (USGS station ID 05046000) were:

- -0.47% error in total flow volume;
- -0.92% error in the bottom 50% low flows;

- -0.73% error in the top 10% high flows;
- A Nash-Sutcliffe coefficient of model fit efficiency of 0.987 for daily flows; and
- A Nash-Sutcliffe coefficient of model fit efficiency of 0.994 for monthly flows.

Overall, the HSPF model accuracy was determined to be “Very Good”, based on performance criteria (Tetra Tech 2017). More information on the calibration of the HSPF model can be found in Tetra Tech (2017). Allocations and loading capacities are based on flow, which varies from very high to very low. The uncertainty in flow variability is accounted for using the five flow regimes and the LDCs. There is no reason to believe a 10% MOS is inappropriate as it is sufficiently representing the HSPF modeling errors. For the Otter Tail River, Unnamed Lake (56-0821-00) to Pelican River (WID 09020103-574) and the Pelican River, Reed Creek to Otter Tail River (WID 09020103-768), the MOS is taken as 10% of the loading capacity minus the boundary condition load.

4.2.6 Seasonal variation and critical conditions

Geometric means for *E. coli* bacteria within the impaired reaches are often above the state chronic standard from April through October. Exceedances of the acute standard were also common in these reaches during this time period. Fecal bacteria such as *E. coli* are most productive at temperatures similar to their origination environment in animal digestive tracts. Thus, these organisms are expected to be at their highest concentrations during warmer summer months when stream flow is low and water temperatures are high. High *E. coli* concentrations in many of the reaches continue into the fall, which may be attributed to constant sources of *E. coli* (such as ITPHS SSTSs and animal access to the stream) or seasonal concentrated sources (such as migrating waterfowl) and less flow for dilution. However, some of the data may be skewed as more samples were collected in the summer months than in October. Seasonal and annual variations are accounted for by setting the TMDL across the entire flow record using the load duration curve method.

4.2.7 TMDL summary

The *E. coli* LDCs and tables follow. It should be noted that some of the numbers in the tables show multiple digits; they are not intended to imply great precision, but rather, this is done primarily to make the arithmetic accurate.

Each table provides a representative load reduction to provide watershed planners a single target reduction to aid in planning that is not dependent on flow conditions. A single, representative load reduction is easier for watershed planners to translate into annual load reductions when developing restoration and protection plans to improve water quality in the watershed. Since *E. coli* is assessed by month, a flow-weighted average of the monthly geometric means of summer months (June through August) was used to determine the representative existing condition. The overall estimated percent reduction is the reduction needed to meet the 126 org/100 mL standard. The estimated percent reductions provide a rough approximation of the overall reduction needed for the waterbody to meet the TMDL. The percent reduction is a means to capture the level of effort needed to reduce *E. coli* concentrations in the watershed. The percent reductions should not be construed to mean that each of the separate sources listed in the TMDL table needs to be reduced by that amount.

Only summer months were used because all impaired stream reaches have data for those months that meet assessment criteria (five sampling days per month) and it allows the load reductions for each stream reach to be comparable to one another, as they represent the same conditions. There is one exception to this. For the Otter Tail River, Unnamed Lake (56-0821-00) to Pelican River (WID 09020103-574), the flow-weighted average monthly geometric mean across all summer months met the 126 org/100 mL standard, and therefore resulted in a negative reduction. In this case, the maximum monthly reduction was taken from the month of August as the load reduction; the August monthly geometric mean and the quantity of samples from the month of August were sufficient to determine that the 126 org/100 mL standard was exceeded and the reach is impaired. Additionally, if two monitoring sites in an impaired reach existed and one station showed a negative reduction, only the station that showed a positive reduction was used. This exception occurred for two reaches, Pelican River, Reed Creek to Otter Tail River (WID 09020103-768) and Toad River, Unnamed Creek to Pine Lake (WID 09020103-770). These exceptions are noted in footnotes below the associated tables and can be used to guide implementation strategies for the applicable reaches.

Baseline years for each TMDL are included in the header of each TMDL table. The baseline year is the year used to provide a reasonable condition for tracking reductions. The baseline year is taken as the year with observed data closest to the median flow condition.

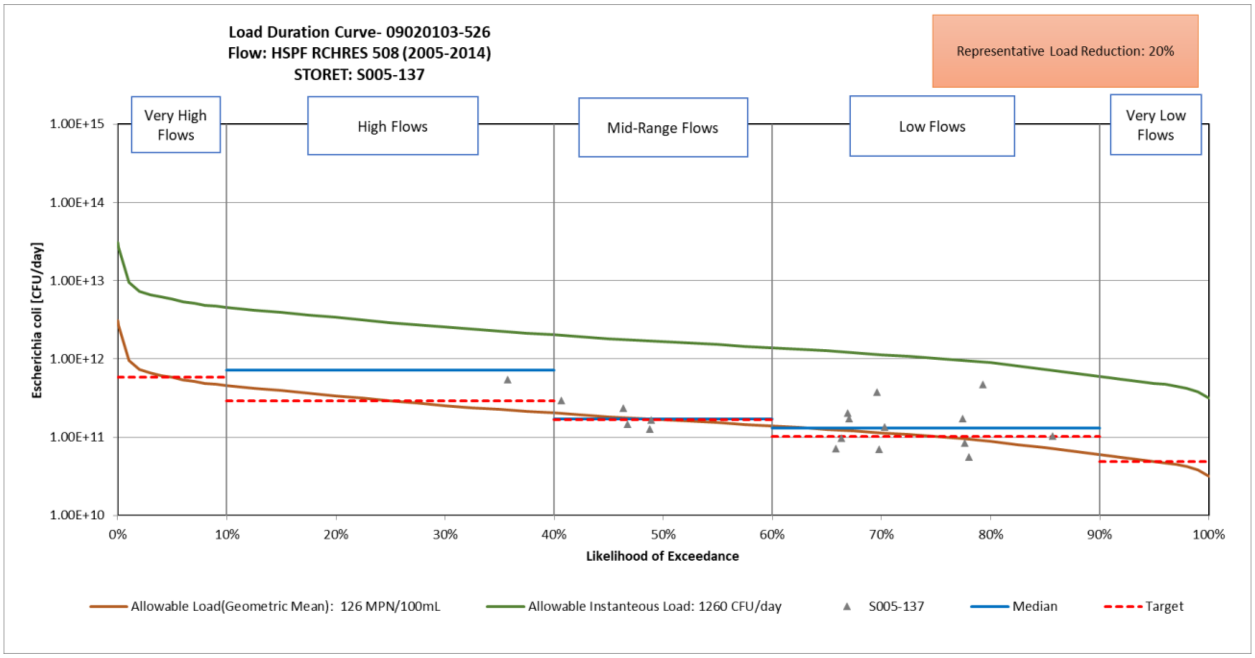


Figure 14. Toad River, Little Toad Lk to T138 R38, SW corner (09020103-526) *E. coli* LDC.

Table 20. *E. coli* allocations for Toad River, Little Toad Lk to T138 R38, SW corner (09020103-526).

Escherichia coli Listing year: 2020 Baseline year: 2008 Numeric WQ standard used: 126 org/100 mL	**Flow Condition**				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	[Billions organisms/day]				
Loading Capacity	**580**	**291**	**166**	**102.5**	**49.0**
Wasteload Allocation	**0**	**0**	**0**	**0**	**0**
Load Allocation	**522**	**262**	**149**	**92.2**	**44.1**
Margin of Safety (MOS)	**58**	**29**	**17**	**10.3**	**4.9**
Average existing monthly geometric mean[1]	**158 org/100 mL**				
Overall estimated percent reduction	**20%**				

[1]Flow-weighted average existing monthly geometric mean taken as the average of summer months (June-August).

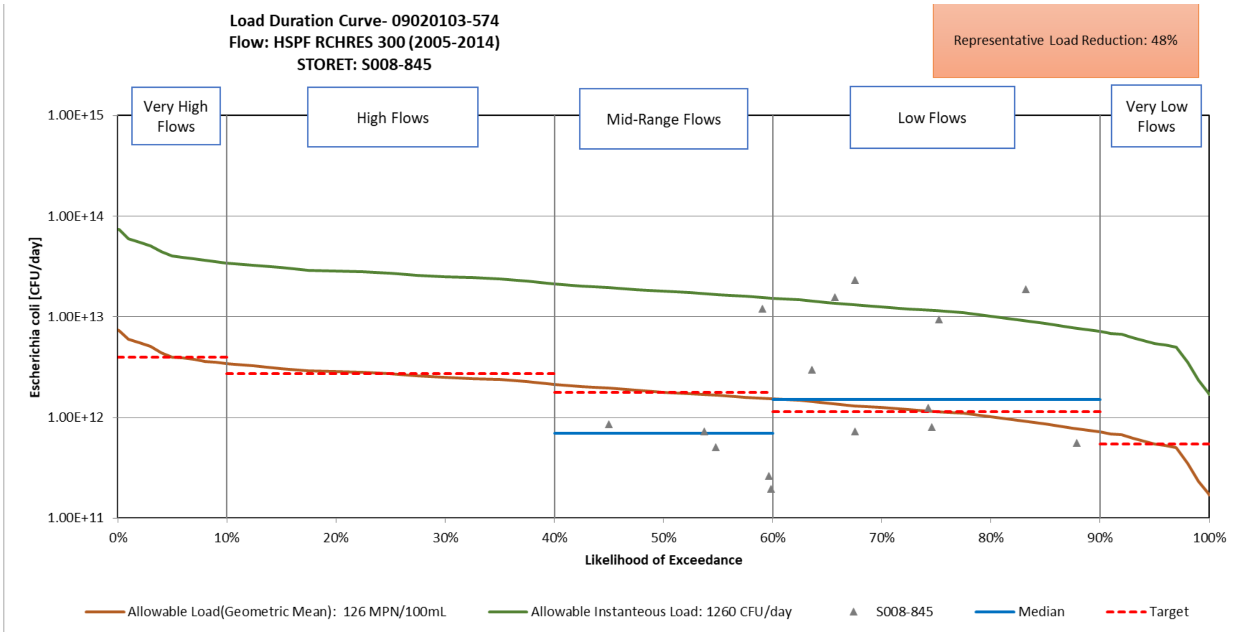


Figure 15. Otter Tail River, Unnamed Lk (56-0821-00) to Pelican R (09020103-574) *E. coli* LDC.

Table 21. *E. coli* allocations for Otter Tail River, Unnamed Lk (56-0821-00) to Pelican R (09020103-574).

Escherichia coli Listing year: 2020 Baseline year: 2016 Numeric WQ standard used: 126 org/100 mL		**Flow Condition**				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		[Billions organisms/day]				
Loading Capacity		**3,994.9**	**2,712.6**	**1,786.6**	**1,148.1**	**544.3**
Boundary Condition Load (at Unnamed Lake (56-1203-00))[1]		**3,869.0**	**2,668.7**	**1,756.5**	**1,127.1**	**537.2**
Remaining Load (LC-BCL)		***125.9***	***43.9***	***30.1***	***21.0***	***7.1***
Wasteload Allocation	*Fergus Falls WWTP*	13.4[2]	###[4]	###[4]	###[4]	###[4]
	Fergus Falls MS4 (MS400268)	91.9[3]	###[4]	###[4]	###[4]	###[4]
	Total WLA	**105.3**	###[4]	###[4]	###[4]	###[4]
Load Allocation	**Total LA**	**8.0**	###[5]	###[5]	###[5]	###[5]
Margin of Safety (MOS)[6]		**12.6**	**4.4**	**3.0**	**2.1**	**0.7**
Maximum monthly geometric mean[7]		**240.2 org/100 mL**				
Overall estimated percent reduction		**48%**				

[1]The boundary condition load was calculated at the outlet of Unnamed Lake (WID 56-1203-00) since HSPF-modeled flow data was available at the lake's outlet, but not where WID 09020103-774 meets the lake's inlet. This assumes the outflow of Unnamed Lake (56-1203-00) meets, and the outflow of Otter Tail River, River Diversion to Unnamed Lake (56-1203-00) (WID 09020103-774) continues to meet, applicable *E. coli* standards (see **Section 4.2.3** for details on the applied boundary condition).
[2]WWTP WLAs were further discussed in **Section 4.2.3** and established in **Table 18**. This WLA is equivalent to the facility's permitted effluent limits and therefore, no additional bacteria reductions are required as long as the permit limits are met.
[3]The portion of the Fergus Falls MS4 within this drainage area represents 73.0% of the contributing boundary condition area, therefore it gets a WLA of 73.0% of the remaining load (loading capacity minus the boundary condition load) (see **Section 4.2.3**).
[4]The combined WWTP permitted design flow and estimated runoff from the permitted MS4 area exceed the remaining load of this flow regime. The allocations are expressed as an equation rather than an absolute number: Allocation = flow contribution of a given source (WWTP or MS4) X 126 org/100 mL *E. coli* concentration standard (see **Section 4.2.4**).
[5]The total WLA exceeded the remaining load for this flow regime, therefore the LA is determined by the formula: Allocation = flow contribution of a given source X 126 org/100 mL *E. coli* concentration standard (see **Section 4.2.4**).
[6]MOS is taken as 10% of the remaining load (loading capacity minus the boundary condition load).
[7]Maximum monthly geometric mean taken from the month of August; flow-weighted summer average monthly geometric mean (June-August) met the 126 org/100 mL standard and resulted in a negative estimated reduction (-6%; 119.3 org/100 mL).

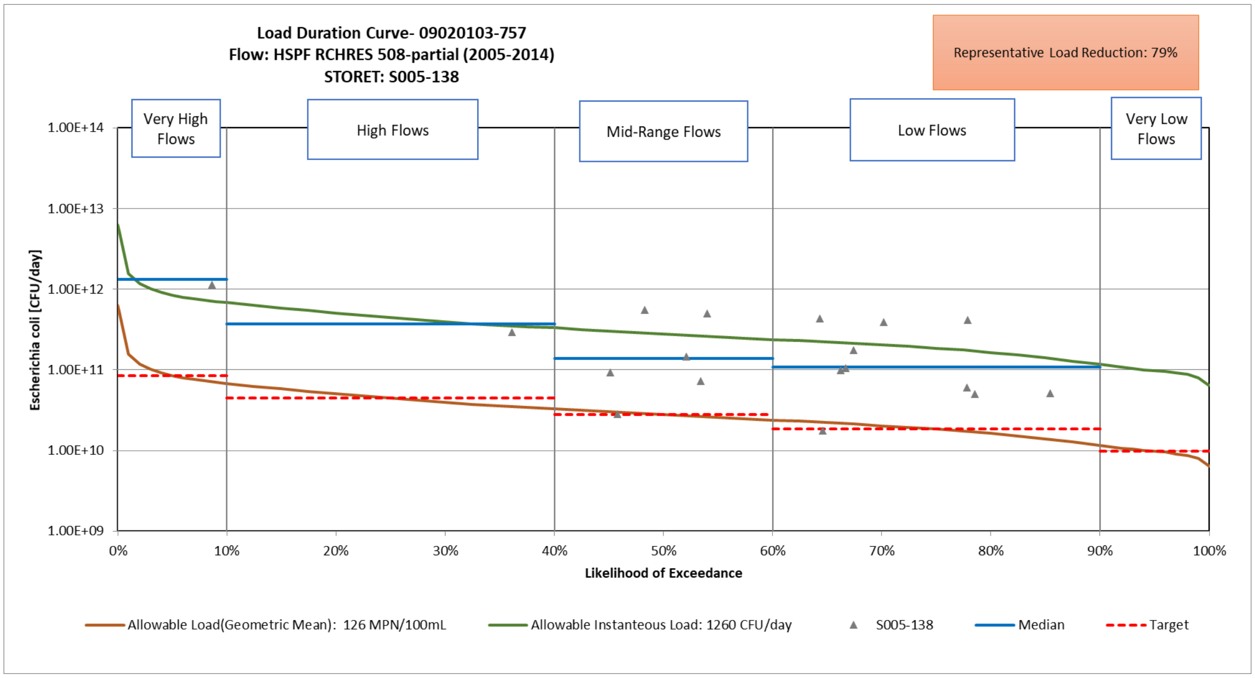


Figure 16. Unnamed Creek, Unnamed Cr to Dead Lk (09020103-757) *E. coli* LDC.

Table 22. *E. coli* allocations for Unnamed Creek, Unnamed Cr to Dead Lk (09020103-757).

Escherichia coli Listing year: 2020 Baseline year: 2008 Numeric WQ standard used: 126 org/100 mL	**Flow Condition**				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	[Billions organisms/day]				
Loading Capacity	**84.4**	**44.6**	**27.9**	**18.6**	**9.84**
Wasteload Allocation	**0**	**0**	**0**	**0**	**0**
Load Allocation	**76.0**	**40.1**	**25.1**	**16.7**	**8.86**
Margin of Safety (MOS)	**8.4**	**4.5**	**2.8**	**1.9**	**0.98**
Average existing monthly geometric mean[1]	**610 org/100 mL**				
Overall estimated percent reduction	**79%**				

[1]Flow-weighted average existing monthly geometric mean taken as the average of summer months (June-August).

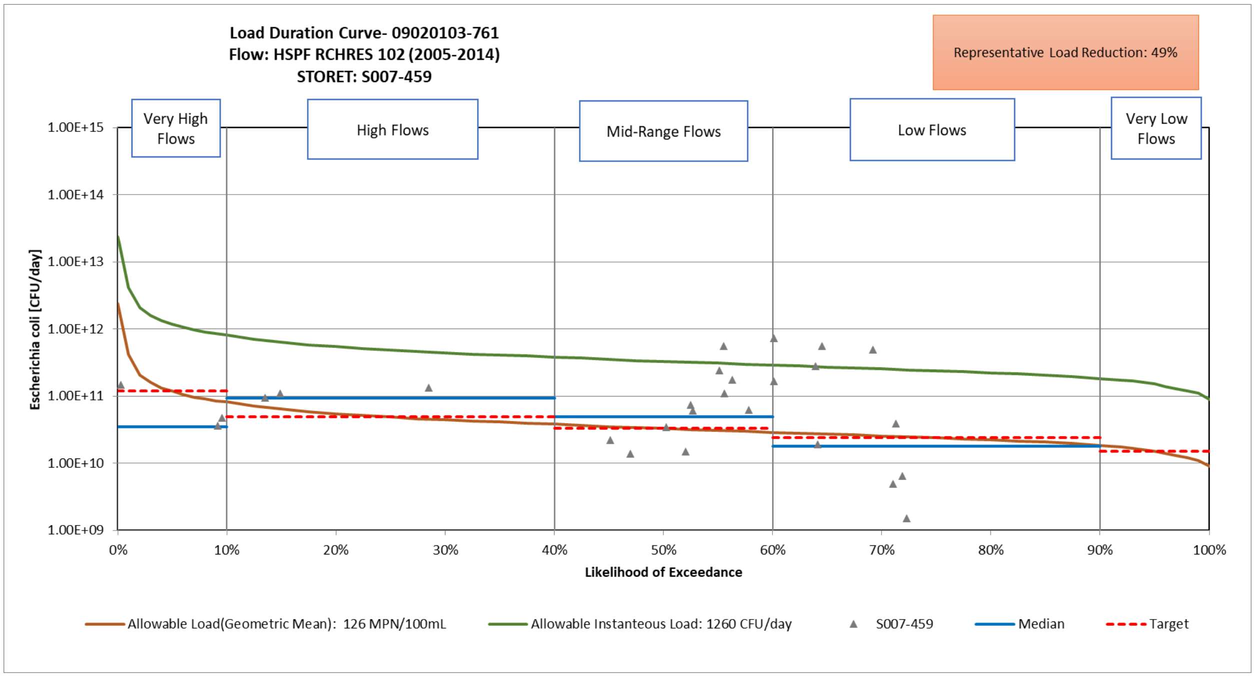


Figure 17. Unnamed Creek, CD 3 to Otter Tail R (09020103-761) *E. coli* LDC.

Table 23. *E. coli* allocations for Unnamed Creek, CD 3 to Otter Tail R (09020103-761).

Escherichia coli Listing year: 2020 Baseline year: 2013 Numeric WQ standard used: 126 org/100 mL	**Flow Condition**				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	[Billions organisms/day]				
Loading Capacity	**118**	**48.7**	**33.0**	**24.0**	**15.1**
Wasteload Allocation	**0**	**0**	**0**	**0**	**0**
Load Allocation	**106**	**43.8**	**29.7**	**21.6**	**13.6**
Margin of Safety (MOS)	**12**	**4.9**	**3.3**	**2.4**	**1.5**
Average existing monthly geometric mean[1]	**246.6 org/100 mL**				
Overall estimated percent reduction	**49%**				

[1]Flow-weighted average existing monthly geometric mean taken as the average of summer months (June-August).

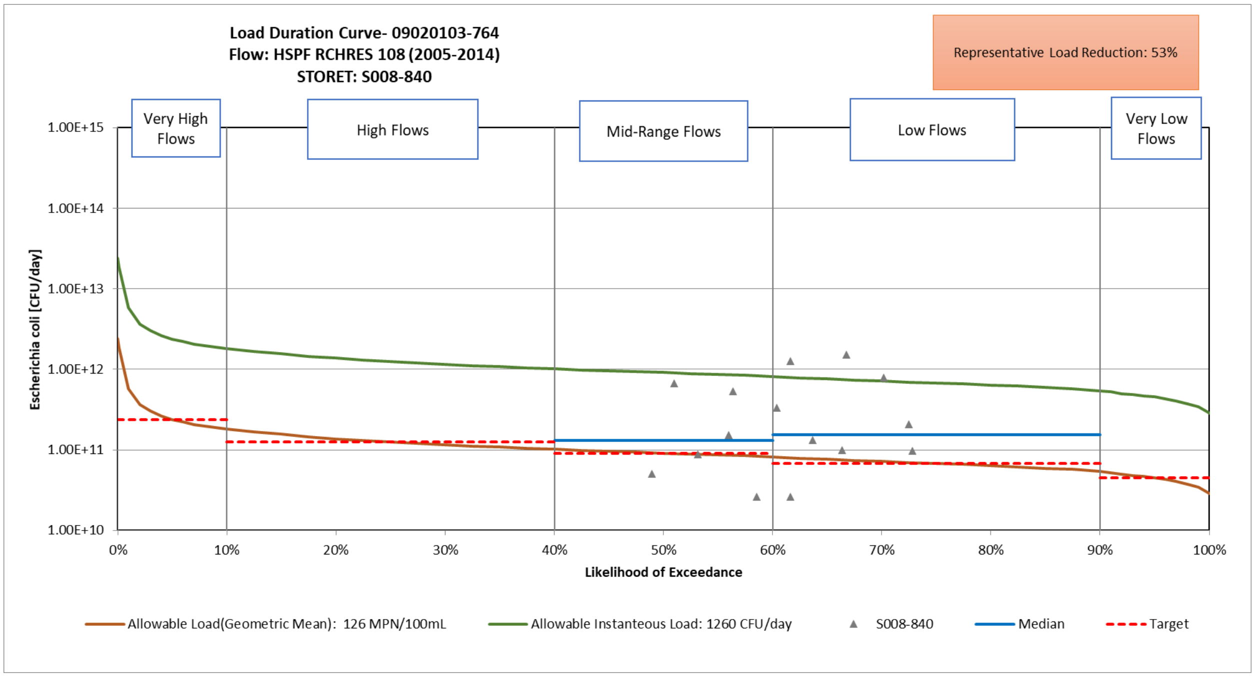


Figure 18. Judicial Ditch 2, Unnamed ditch along 190th St to Otter Tail R (09020103-764) *E. coli* LDC.

Table 24. *E. coli* allocations for Judicial Ditch 2, Unnamed ditch along 190th St to Otter Tail R (09020103-764).

Escherichia coli Listing year: 2020 Baseline year: 2016 Numeric WQ standard used: 126 org/100 mL	**Flow Condition**				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	[Billions organisms/day]				
Loading Capacity	**238**	**125**	**91.1**	**68.0**	**45.4**
Wasteload Allocation	**0**	**0**	**0**	**0**	**0**
Load Allocation	**214**	**112**	**82.0**	**61.2**	**40.9**
Margin of Safety (MOS)	**24**	**13**	**9.1**	**6.8**	**4.5**
Average existing monthly geometric mean[1]	**268.2 org/100 mL**				
Overall estimated percent reduction	**53%**				

[1]Flow-weighted average existing monthly geometric mean taken as the average of summer months (June-August).

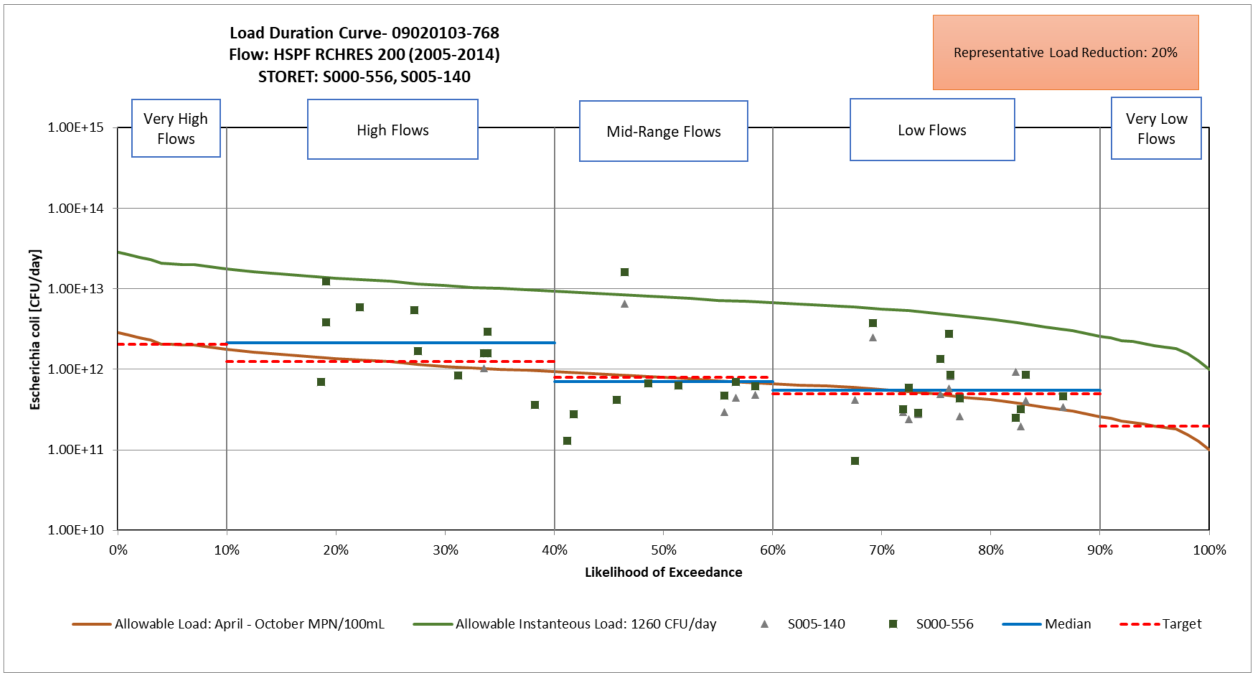


Figure 19. Pelican River, Reed Cr to Otter Tail R (09020103-768) *E. coli* LDC.

Table 25. *E. coli* allocations for Pelican River, Reed Cr to Otter Tail R (09020103-768).

Escherichia coli Listing year: 2020 Baseline year: 2008 Numeric WQ standard used: 126 org/100 mL		Flow Condition				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		[Billions organisms/day]				
Loading Capacity		**2,045.02**	**1,241.21**	**789.82**	**494.28**	**196.60**
Boundary Condition Load (at Reed Creek)[1]		**1,785.29**	**1,157.37**	**733.87**	**455.88**	**181.94**
Remaining Load (LC-BCL)		***259.73***	***83.84***	***55.95***	***38.40***	***14.66***
Wasteload Allocation	*Elizabeth WWTP[2]*	1.38	1.38	1.38	1.38	1.38
	Fergus Falls (MS400268)[3]	6.25	2.02	1.35	0.92	0.35
	Total WLA	**7.63**	**3.40**	**2.73**	**2.30**	**1.73**
Load Allocation	**Total LA**	**226.13**	**72.06**	**47.62**	**32.26**	**11.46**
Margin of Safety (MOS)[4]		**25.97**	**8.38**	**5.60**	**3.84**	**1.47**
Average existing monthly geometric mean[5]		**157.4 org/100 mL**				
Overall estimated percent reduction		**20%**				

[1]The boundary condition load was calculated at the outlets of the Pelican River, Lake Lizzie to Reed Creek (WID 09020103-767) and Reed Creek, Reed Lake to Pelican River (WID 09020103-653), and assumes their combined flows entering the impaired reach continue to meet applicable *E. coli* standards (see **Section 4.2.3** for additional details on the applied boundary condition).
[2]WWTP WLAs were further discussed in **Section 4.2.3** and established in **Table 18**. This WLA is equivalent to the facility's permitted effluent limits and therefore, no additional bacteria reductions are required as long as the permit limits are met.
[3]The portion of the Fergus Falls MS4 within this drainage area represents 2.41% of the contributing boundary condition area, therefore it gets a WLA of 2.41% of the remaining load (loading capacity minus the boundary condition load) (see **Section 4.2.3**). To meet the MS4 WLA, *E. coli* loading from the applicable Fergus Falls MS4 area does not need to be reduced but is not allowed to increase (see **Section 3.6.1.2**).
[4]MOS is taken as 10% of the remaining load (loading capacity minus the boundary condition load).
[5]Flow-weighted average existing monthly geometric mean taken as the average of summer months (June-August) at monitoring site S000-556 at the downstream end of the WID. Monitoring site S005-140, at the approximate mid-point of the WID, resulted in a flow-weighted summer average monthly geometric mean with a negative estimated reduction (-4%; 121.5 org/100 mL).

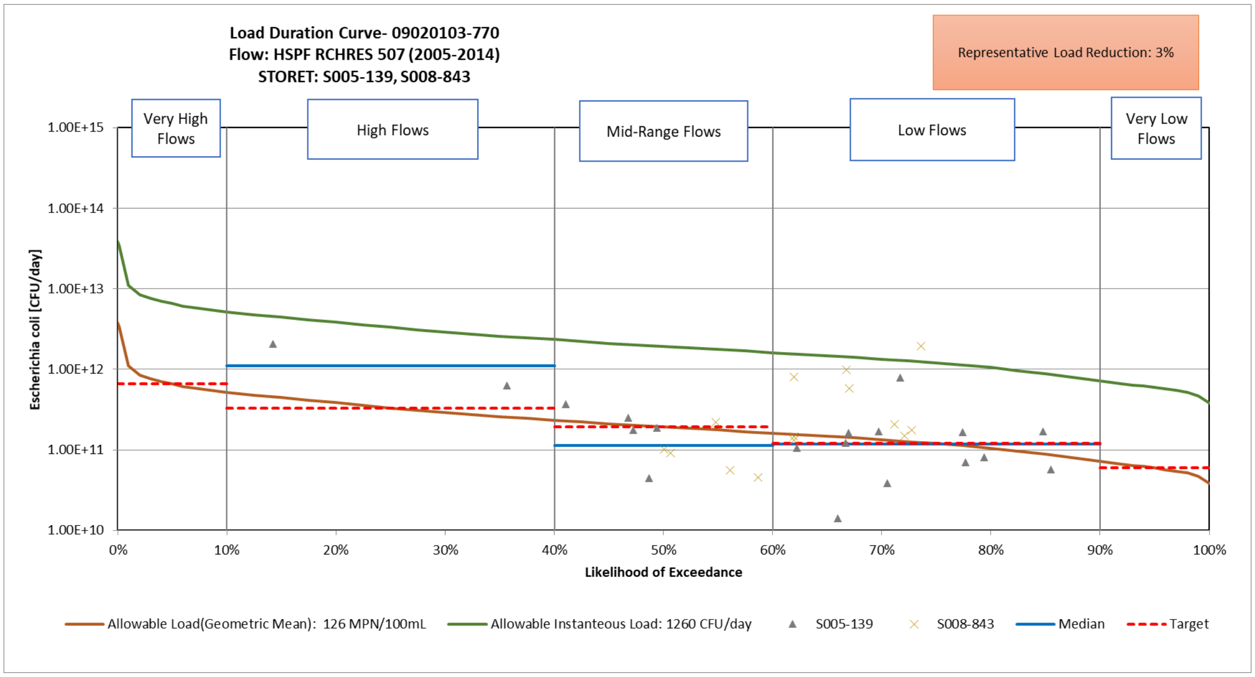


Figure 20. Toad River, Unnamed Cr to Pine Lk (09020103-770) *E. coli* LDC.

Table 26. *E. coli* allocations for Toad River, Unnamed Cr to Pine Lk (09020103-770).

Escherichia coli Listing year: 2020 Baseline year: 2008 Numeric WQ standard used: 126 org/100 mL	**Flow Condition**				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	[Billions organisms/day]				
Loading Capacity	**660**	**331**	**192**	**120.0**	**59.6**
Wasteload Allocation	**0**	**0**	**0**	**0**	**0**
Load Allocation	**594**	**298**	**173**	**108.0**	**53.6**
Margin of Safety (MOS)	**66**	**33**	**19**	**12.0**	**6.0**
Average existing monthly geometric mean[1]	**130.5 org/100 mL**				
Overall estimated percent reduction	**3%**				

[1]Flow-weighted average existing monthly geometric mean taken as the average of summer months (June-August)at monitoring site S005-139 at the downstream end of the WID. Monitoring site S008-843, approximately one mile upstream, resulted in a flow-weighted summer average monthly geometric mean with a negative estimated reduction (-8%; 117 org/100 mL).

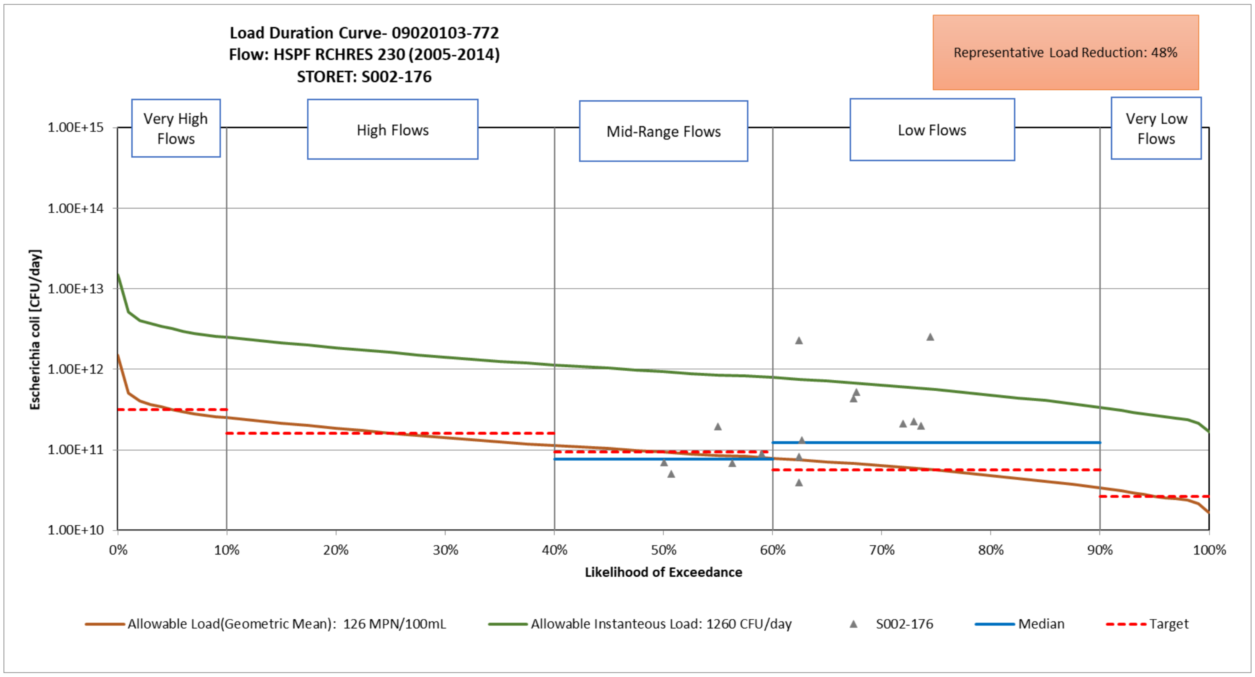


Figure 21. Pelican River, Highway 10 to Detroit Lk (09020103-772) *E. coli* LDC.

Table 27. *E. coli* allocations for Pelican River, Highway 10 to Detroit Lk (09020103-772).

Escherichia coli Listing year: 2020 Baseline year: 2016 Numeric WQ standard used: 126 org/100 mL		**Flow Condition**				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		[Billions organisms/day]				
Loading Capacity		**319**	**162.0**	**93.8**	**55.92**	**26.58**
Wasteload Allocation	*Detroit Lakes (MS400230)*[1]	16	8.1	4.7	2.80	1.33
	Total WLA	**16**	**8.1**	**4.7**	**2.80**	**1.33**
Load Allocation	**Total LA**	**271**	**137.7**	**79.7**	**47.53**	**22.59**
Margin of Safety (MOS)		**32**	**16.2**	**9.4**	**5.59**	**2.66**
Average existing monthly geometric mean[2]		**241.0 org/100 mL**				
Overall estimated percent reduction		**48%**				

[1]The portion of the Detroit Lakes MS4 within this drainage area represents 5.01% of the contributing drainage area, therefore it gets a WLA of 5.01% of the loading capacity (see **Section 4.2.3**).
[2]Average existing monthly geometric mean taken as the average of summer months (June-August).

4.3 Total Suspended Solids

4.3.1 Loading capacity methodology

As for *E. coli*, LDCs were used to represent the LC for each TSS impaired reach. Description of the LDC methodology can be found in **Section 4.2.1**. The flow component of the LC curve is based on the HSPF-simulated daily average flows (2005 through 2014), and the concentration component is the TSS concentration criteria of 30 mg/L for the CRNR. TSS LDCs for each impaired reach are shown in **Section 4.3.6**. The red curve in these figures represents the allowable TSS LC of the reach for each daily flow. The median (or midpoint) load of each flow zone is used to represent the total loading capacity in the TMDL tables.

Table 28 provides the methodology and conversion factors to transform flows and concentrations to loads. The TSS standard-based LDCs were created using the CRNR TSS standard of 30 mg/L. The TSS standard only applies during the months of April through September. Loads for TSS are calculated as tons/day.

Table 28. Converting flow and concentration to sediment load.

Load (tons/day) = TSS standard (30 mg/L) * Flow (cfs) * Conversion Factor			
For each flow regime			
Multiply **flow** (cfs) by **28.31** (L/ft^3)[1] and **86,400** (sec/day) to convert	cfs	→	L/day[1]
Multiply **TSS Standard** (30 mg/L) by **L/day** to convert	L/day	→	mg/day[1]
Divide **mg/day** by **907,184,740** (mg/ton) to convert	mg/day	→	tons/day

[1]L/ft^3: liters per cubic foot; L/day: liters per day; mg/day: milligrams per day

It should be noted that some observed TSS data were collected outside the period of available flows (2005 through 2014). Therefore, existing conditions could not be estimated without flow transfer to determine flow conditions on the days when samples were collected. A flow transfer was developed using the closest USGS gage (USGS# 05460000) with a sufficient data record to complete the flow transfer. The flow transfer was conducted by developing a linear regression equation **(Table 29)** comparing the distributions of flows at the USGS gaging station and the simulated flows in the impaired reach for the LDC period (2005 through 2014). Once the regression equation was developed, the percent exceedance of the observed day was calculated and transformed using the regression equation. Then the absolute flow was estimated by finding the flow of the transfer flow exceedance using the simulated flow distribution (from HSPF).

Table 29. Flow transfer equations used to develop existing conditions in TSS TMDLs.

WID (Stream Name)	HSPF RCHRES ID	Transfer Flow Site (USGS ID)	Transfer Equation[1]	R^2
09020301-504 (Otter Tail R)	104	USGS 05046000	$\%Model_I = 0.984562*\%Obs_I + 0.005561$	0.963
09020301-543 (Campbell Cr)	232	USGS 05046000	$\%Model_I = 0.597743*\%Obs_{I-5} + 0.199631$	0.355

[1]$\%Model_I$ = the percent exceedance of the model flow, and $\%Obs_I$ = the percent exceedance of the observed flow.

4.3.2 Load allocation methodology

LAs represent the portion of the LC designated for nonpermitted or NPS of TSS. The LA is the remaining load once the WLA and MOS are determined and subtracted from the LC. The LA includes all sources of TSS that do not require NPDES/SDS permit coverage, including unregulated watershed runoff, atmospheric deposition, and a consideration for natural background conditions previously discussed in **Section 4.1.1**. NPS of TSS were previously discussed in **Section 3.6.2.2.**

4.3.3 Wasteload allocation methodology

WLAs are developed for any permitted discharge in the drainage area of an impaired reach. These are discharges requiring an NPDES/SDS permit, and typically include wastewater treatment facilities, permitted MS4s, industrial wastewater or stormwater discharges, construction stormwater, and permitted feedlots. All WLAs developed in this TMDL are equivalent to or consistent with current permitted effluent limits where they apply. Therefore, no new or additional reductions are necessary at any permitted facilities with regulated effluent limits, such as WWTPs. However, this may not apply to permittees with no specifically permitted effluent limits, such as permitted construction sites.

Boundary Condition

For the Otter Tail River, JD 2 to Breckenridge Lake (WID 09020103-504), a boundary condition was applied. The Orwell Dam and Orwell Reservoir, approximately seven river miles upstream of this impaired reach, acts like a sink for most sediment and solids from the upstream watershed and provides an upper boundary for the lower portion of the Otter Tail River. This boundary is also applied because the TSS water quality standard is met by the calculated outflow of the Orwell Dam. Additionally, this boundary condition concept was applied in the same way for the Lower Otter Tail River Turbidity Total Maximum Daily Load Report (MPCA 2006), developed for the Otter Tail River from Breckenridge Lake to the Bois de Sioux River (WID 09020103-502), the stream reach directly downstream of this impaired reach (-504). With the boundary condition applied, the only WLAs included in the TMDL for the Otter Tail River (-504) will be for areas and dischargers downstream of the Orwell Reservoir. The inflow at the upper boundary (Orwell Dam outflow) assumes that the water quality standards are met there and takes into account for the MOS and any applicable WLAs upstream of the dam.

Domestic and Industrial Wastewater

There are no domestic WWTPs or industrial wastewater dischargers downstream of the Orwell boundary condition for Otter Tail River (WID 09020103-504), and no WWTPs or industrial wastewater dischargers within the drainage area of Campbell Creek (WID 09020103-543). Therefore, no wastewater dischargers were assigned a TSS WLA.

Straight Pipe Septic Systems

Straight pipe septic systems are illegal and unpermitted and receive a WLA of zero. Failing SSTS and ITPHS systems are assessed as nonpermitted sources, and would be accounted for in the LA portion of the TMDL.

Construction and Industrial Permits

WLAs for discharge sites covered under the Construction Stormwater General Permit (NPDES/SDS permit# MNR100001) and the Industrial Stormwater General Permits (NPDES/SDS permit# MNR050000 or MNG490000) were combined and addressed through a categorical allocation. Stormwater runoff from construction sites that disturb: (a) one acre of soil or more, (b) less than one acre of soil and are part of a "larger common plan of development or sale" that is greater than one acre, or (c) less than one acre, but have been determined to pose a risk to water quality are regulated under the state's NPDES/SDS Construction Stormwater General Permit (MNR100001). This permit requires and identifies BMPs to be implemented to protect water resources from mobilized sediment and other pollutants of concern. If the owner/operators of impacted construction sites obtain and abide by the NPDES/SDS Construction Stormwater General Permit, the stormwater discharges associated with those sites are expected to meet the WLAs set in this TMDL report.

Similar to construction activities, industrial sites are regulated under general permits, in this case either the NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or the NPDES/SDS Nonmetallic Mining/Associated Activities General Permit (MNG490000). Like the NPDES/SDS Construction Stormwater General Permit, these permits identify BMPs to be implemented to protect water resources from pollutant discharges at the site. If the owner/operators of industrial sites abide by the necessary NPDES/SDS Stormwater General Permits, the discharges associated with those sites are expected to meet the WLAs set in this TMDL report.

According to MPCA construction stormwater permit data, an average of 0.3% of the entire OTRW area was covered under the NPDES/SDS Construction Stormwater General Permit per year over the last five years (MPCA 2020m). Furthermore, there are currently no NPDES/SDS permitted industrial stormwater facilities in the drainage area for Campbell Creek (WID 09020103-543), and there are currently no permitted industrial stormwater facilities in the drainage area for Otter Tail River (WID 09020103-504) downstream of the Orwell Dam. Therefore, to calculate the WLA for construction and industrial stormwater, this TMDL report assumes that 0.3% of the applicable loading capacity for the stream reach is assigned to the construction/industrial stormwater WLA. For Otter Tail River (-504), the WLA for construction and industrial stormwater is taken as 0.3% of the loading capacity minus the boundary condition load.

Municipal Separate Storm Sewer System

There are no MS4s downstream of the Orwell boundary condition for Otter Tail River (WID 09020103-504) and no MS4s within the drainage area of Campbell Creek (WID 09020103-543). Therefore, no MS4 areas were assigned a TSS WLA.

Animal Feedlots

NPDES and SDS permitted feedlot facilities and CAFOs not requiring permits are assigned a zero WLA. This is consistent with the conditions of the permits and the design and operation standards and requirements for CAFOs in Minnesota, which allow no pollutant discharge from the livestock housing facilities and associated manure storage areas. Furthermore, there are currently no CAFO feedlots downstream of the Orwell boundary condition for Otter Tail River (WID 09020103-504) and no CAFO feedlots within the drainage area of Campbell Creek (WID 09020103-543). Therefore, no CAFO feedlots were assigned a TSS WLA. Discharge of sediment from non-CAFO feedlots and fields where manure has been stockpiled or land-applied may occur during runoff events, but those discharges are covered under the LA portion of the TMDL and do not require an additional WLA.

4.3.4 Margin of safety

The purpose of the MOS is to account for uncertainty with the allocations resulting in attaining water quality standards. Uncertainty can be associated with data collection, lab analysis, data analysis, modeling error, and implementation activities. An explicit 10% of the LC MOS was applied to each flow regime for all LDCs developed for this TMDL report. The LDC approach minimizes a great deal of uncertainty. The explicit 10% MOS accounts for:

- Uncertainty in the simulated flow data from the HSPF model;
- Uncertainty in the observed water quality data; and
- Uncertainty in the observed data describing the current water quality conditions.

The majority of the MOS is apportioned to uncertainty related to the HSPF model, over the other causes for uncertainty. The hydrologic calibration statistics for the HSPF model at the Otter Tail River below Orwell Dam near Fergus Falls, Minnesota (USGS station ID 05046000) were:

- -0.47% error in total flow volume;
- -0.92% error in the bottom 50% low flows;
- -0.73% error in the top 10% high flows;
- A Nash-Sutcliffe coefficient of model fit efficiency of 0.987 for daily flows; and
- A Nash-Sutcliffe coefficient of model fit efficiency of 0.994 for monthly flows.

Overall, the accuracy of the HSPF model was determined to be “Very Good”, based on performance criteria (Tetra Tech 2017). More information on the calibration of the HSPF model can be found in Tetra Tech (2017).

Allocations and loading capacities are based on flow, which varies from very high to very low. This variability is accounted for using the five flow regimes and the LDCs. There is no reason to believe a 10% MOS is inappropriate as it is consistent with HSPF modeling errors. For the Otter Tail River (WID 09020103-504), the MOS is taken as 10% of the loading capacity minus the boundary condition load.

4.3.5 Seasonal variation and critical conditions

Both seasonal variation and critical conditions are accounted for in this TMDL report through the application of LDCs. LDCs evaluate water quality conditions across all flow zones including high flow, runoff conditions where sediment transport tends to be greatest. Seasonality is accounted for by addressing all flow conditions in a given reach. The maximum load reduction for both TSS TMDLs occurs during high flow conditions.

4.3.6 TMDL summary

The TSS LDCs and tables follow. It should be noted that some of the numbers in the tables show multiple digits; they are not intended to imply great precision, but rather, this is done primarily to make the arithmetic accurate.

Each table has a representative load reduction to provide watershed planners a single target reduction that is not dependent on flow conditions to aid in planning. A single, representative load reduction is easier for watershed planners to translate into annual load reductions when developing restoration and protection plans to improve water quality in the watershed. For TSS, the representative existing condition is taken as the 90th percentile of the observed TSS concentrations. The overall estimated percent reduction is the reduction of the existing condition to meet the 30 mg/L standard. The estimated percent reductions provide a rough approximation of the overall reduction needed for the waterbody to meet the TMDL. The percent reduction is a means to capture the level of effort needed to reduce TSS concentrations in the watershed. The percent reductions should not be construed to mean that each of the separate sources listed in the TMDL table needs to be reduced by that amount.

Baseline years for each TMDL are included in the header for each TMDL table. The baseline year is the year used to provide a reasonable condition for tracking reductions. The baseline year is taken as the year with observed data closest to the median flow condition.

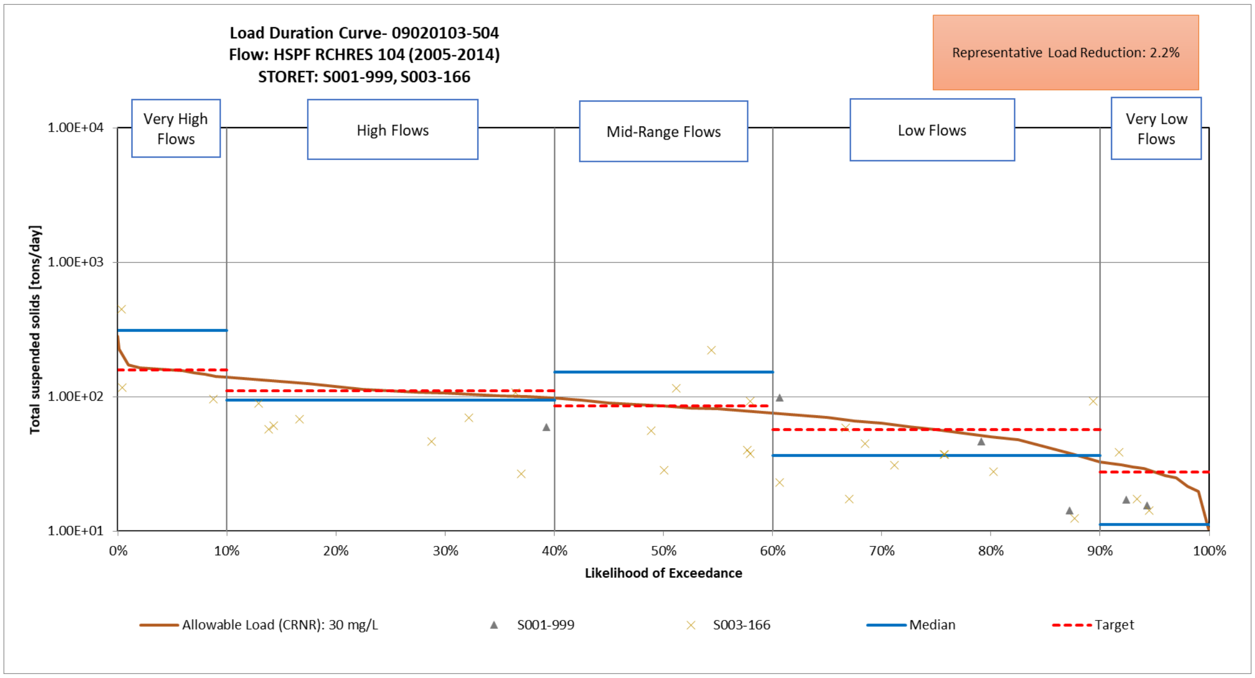


Figure 22. Otter Tail River, JD 2 to Breckenridge Lk (09020103-504) TSS LDC.

Table 30. TSS allocations for Otter Tail River, JD 2 to Breckenridge Lk (09020103-504).

Total Suspended Solids Listing year: 2004 Baseline year: 2013 Numeric WQ standard used: 30 mg/L		**Flow Condition**				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		[tons/day]				
Loading Capacity		**158.65**	**110.71**	**84.98**	**56.69**	**27.48**
Boundary Condition Load (at Orwell Dam)[1]		**123.76**	**74.30**	**50.91**	**35.19**	**14.87**
Remaining Load (LC – BCL)		***34.89***	***36.41***	***34.07***	***21.50***	***12.61***
Wasteload Allocation	*Construction/Industrial Stormwater[2]*	0.10	0.11	0.10	0.06	0.04
	Total WLA	**0.10**	**0.11**	**0.10**	**0.06**	**0.04**
Load Allocation	**Total LA**	**31.30**	**32.66**	**30.56**	**19.29**	**11.31**
Margin of Safety (MOS)[3]		**3.49**	**3.64**	**3.41**	**2.15**	**1.26**
90th Percentile Concentration		**30.7 mg/L**				
Overall estimated percent reduction[4]		**2.2%**				

[1]Assumes outflow from Orwell Dam meets applicable TSS water quality standards.

[2]Assumes 0.3% of the remaining load for the boundary condition area downstream of Orwell Dam (loading capacity minus the boundary condition load) is under construction or industrial activities at any given time.

[3] MOS is taken as 10% of the remaining load (loading capacity minus the boundary condition load).

[4]Overall load reduction based on the 90th percentile of all observed TSS data and the 30 mg/L water quality standard.

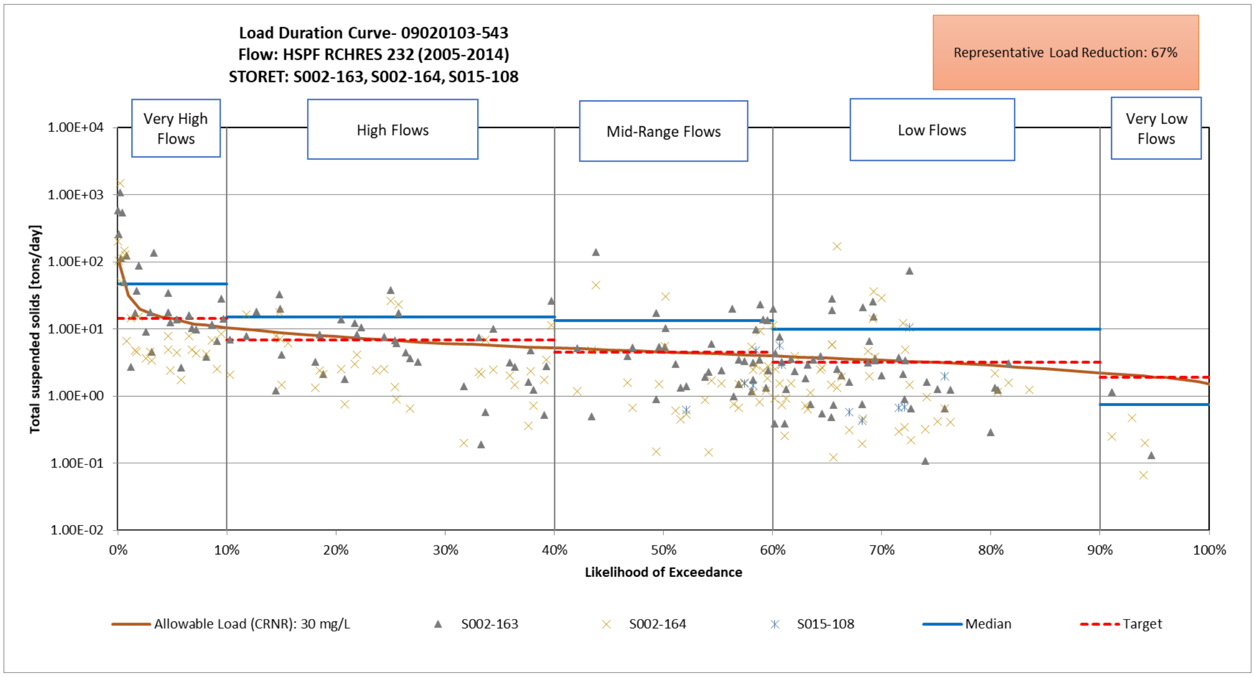


Figure 23. Campbell Creek, Campbell Lk to Floyd Lk (09020103-543) TSS LDC.

Table 31. TSS allocations for Campbell Creek, Campbell Lk to Floyd Lk (09020103-543).

Total Suspended Solids Listing year: 2020 Baseline year: 2013 Numeric WQ standard used: 30 mg/L		**Flow Condition**				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		[tons/day]				
Loading Capacity		**14.22**	**6.86**	**4.56**	**3.180**	**1.931**
Wasteload Allocation	*Construction/Industrial Stormwater*[1]	0.04	0.02	0.01	0.010	0.006
	Total WLA	**0.04**	**0.02**	**0.01**	**0.010**	**0.006**
Load Allocation	**Total LA**	**12.76**	**6.15**	**4.09**	**2.852**	**1.732**
Margin of Safety (MOS)		**1.42**	**0.69**	**0.46**	**0.318**	**0.193**
90th Percentile Concentration		**91.2 mg/L**				
Overall estimated percent reduction[2]		**67%**				

[1]Assumes 0.3% of drainage area is under construction or industrial activities at any given time.
[2]Overall load reduction based on the 90th percentile of all observed TSS data and the 30 mg/L water quality standard.

4.4 Lake Nutrients

4.4.1 Loading capacity methodology

The LC of a lake is the amount of P that can enter a lake over a defined amount of time (daily, annually, etc.) before it exceeds the numeric water quality standard. The LC in impaired lakes in the OTRW were determined using a spreadsheet version of the BATHTUB model currently available as a “beta” version from Walker (1989). BATHTUB is a steady-state model that simulates eutrophication-related water quality conditions in lakes and reservoirs by applying a suite of empirical eutrophication models, formulating water and nutrient balances that account for advective transport, diffuse transport, and nutrient sedimentation. The BATHTUB modeling efforts are further described below and in **Appendix 5.**

Watershed Loading Rates

The overland flows and P loading rates were extracted from the Otter Tail River Basin HSPF model (Tetra Tech 2017) and used in the BATHTUB models. The HSPF model simulates hydrology and water quality for the period 1995 through 2014. None of the impaired lakes addressed in this TMDL report were explicitly modeled in the Otter Tail River Basin HSPF model. Loads to the lakes were derived by summing the hydrology and loading rates from individual hydraulic response units within the lakesheds of each lake and assumed to flow directly into the lake. An annual scale was used to develop the flow and precipitation loading to the lake models and simulate water quality in the BATHTUB models.

Atmospheric Deposition

Atmospheric deposition refers to the P deposited directly to the lake’s surface from the atmosphere. The lakes in the OTRW use an estimated mean annual atmospheric deposition load of 26.1 kg/km^2/yr (0.261 kg/ha/yr; Barr 2007). When summer values are used, the ratio of summer precipitation to average annual precipitation is used to estimate the summer atmospheric deposition.

Internal Loading

Internal loading is the re-release of TP from sediments, usually due to anoxic conditions (DO concentrations < 2.0 mg/L) near the bed of the lake. Internal P loading can be a substantial part of the mass balance in a lake, especially in lakes with a history of high P loads. If a lake has a long history of high P concentrations, it is possible to have internal loading rates higher than external loads. There was no information on specific internal loading in lakes in the OTRW at the time of this TMDL report, therefore, internal loading rates (if needed) were determined using two mass balance approaches. The first was a mass balance approach developed by Nurnberg and described below to check if an “additional” internal load is necessary to meet in-lake P concentrations. Second, if the Nurnberg equation showed the need for an “additional” load, the internal loads were used to calibrate the BATHTUB models, i.e., additional loads were added to the lake models until in-lake P concentrations were met.

The need for an “additional” internal load was checked using methodology developed by Nurnberg (1984), referred to as the mass balance approach. Internal loading is estimated by adding an internal loading term to the current models based on external loading and predicted retention (Nurnberg 1984):

$$TP = {L_{ext}}/{q_s}\left(1 - R_{pred}\right) + {L_{int}}/{q_s} \qquad [1]$$

where TP is the in-lake TP concentration (µg/L); L_{ext} is the external load (kg/yr), q_s is the lake outflow (hm^3/yr), R_{pred} is the predicted retention coefficient, and L_{int} is the internal loading (kg/yr). The retention coefficient can be estimated using:

$$R_{pred} = {}^{15}\Big/\left(18 + {}^{q_s}/_{A}\right) \qquad [2]$$

where A = surface area of the lake (km^2). The only unknown in [1] and [2] is internal loading and it can be estimated by solving for L*int*.

Using equations [1] and [2], and given external loading rates (from HSPF), the potential for internal loading was checked for the modeled lakes. All modeled lakes showed the need for an explicit internal load.

Next, the BATHTUB P model was set to the Canfield and Bachman Natural Lakes model and the calibration coefficient was set to one. Additional P loads were added to the lake models until modeled in-lake P concentrations matched the observed data described in **Section 3.5**. It should be noted, these estimated "additional" internal loads include the lake's internal loading, any unknown or unquantified loads that were not included in the currently available data (e.g. additional, unidentified loading from surface loads, animal feedlot runoff, SSTS), and any model uncertainty.

Table 32 provides the estimated internal loads, an annualized internal loading rate (averaged over a 365-day calendar year), and the percentage of total load to a lake from internal loading. All lakes showed the need for an "additional" load using the Nurnberg methodology, but when estimating the internal loading in BATHTUB, Johnson Lake showed no need for an additional load. It is assumed that any internal loading in Johnson Lake is covered by the internal loading implicitly included in the BATHTUB model equations and no "additional" loading was required for the Johnson Lake model to match the observed in-lake TP data.

Table 32. Estimated internal loading rates in the impaired lakes addressed in this TMDL report.

Lake Name	WID	Existing P Load [lbs/yr]	Estimated Internal loading [lbs/yr]	Internal loading yields [mg/m2/day]	Percent of total load
Wine	03-0398-00	78	41	0.41	52.6%
Long	56-0210-00	4,294	3,710	1.04	86.4%
Crooked	56-0458-00	468	227	0.53	48.5%
West Spirit	56-0502-00	426	322	0.38	75.6%
Norway (East Bay)	56-0569-01	1,507	1,314	1.29	87.2%
Norway (West Bay)	56-0569-02	1,229	800	2.64	65.1%
Unnamed	56-0791-00	1,069	809	1.78	75.7%
Devils	56-0882-00	1,148	800	0.80	69.7%
Grandrud	56-0907-00	210	116	0.31	55.2%
Johnson	56-0979-00	333	0	0	0.0%
Oscar	56-0982-00	3,487	1,323	1.21	37.9%
Hovland	56-1014-00	2,587	2,048	3.48	79.2%
Twin	56-1525-00	806	607	1.03	75.4%

4.4.2 Load allocation methodology

LAs represent the portion of the LC designated for nonpermitted or NPS of P. The LA is the remaining load once the WLA and MOS are determined and subtracted from the LC. The LA includes all sources of TP that do not require NPDES/SDS permit coverage, including unregulated watershed runoff, internal loading or unknown loads, groundwater, atmospheric deposition, and a consideration for natural background conditions as discussed in **Section 4.1.1**. NPS of TP were previously discussed in **Section 3.6.3.2.**

4.4.3 Wasteload allocation methodology

WLAs were developed for any permitted discharge in the drainage area of an impaired lake. These are discharges requiring an NPDES/SDS permit, and typically include wastewater treatment facilities, MS4s, industrial wastewater or stormwater dischargers, construction sites managing for stormwater, and permitted feedlots. All WLAs developed in this TMDL are equivalent to or consistent with current permitted effluent limits where they apply. Therefore, no new or additional reductions are necessary at any permitted facilities with regulated effluent limits. However, this may not apply to permittees with no specifically permitted effluent limits.

Domestic and Industrial Wastewater

There are no domestic WWTPs or industrial wastewater dischargers within the drainage areas of any impaired lake covered by this TMDL report. Therefore, no wastewater dischargers were assigned a WLA.

Straight Pipe Septic Systems

Straight pipe septic systems are illegal and unpermitted and receive WLA of zero. Failing SSTS and ITPHS systems are assessed as nonpermitted sources and are accounted for in the LA portion of the TMDL.

Municipal Separation Storm Sewer System (MS4)

There are no MS4 areas within the drainage areas of any impaired lake addressed in this TMDL report. Therefore, no MS4 areas were assigned a WLA.

Construction and Industrial Permits

WLAs for discharge sites covered under the Construction Stormwater General Permit (NPDES/SDS permit# MNR100001) and the Industrial Stormwater General Permits (NPDES/SDS permit# MNR050000 or MNG490000) were combined and addressed through a categorical allocation. Stormwater runoff from construction sites that disturb: (a) one acre of soil or more, (b) less than one acre of soil and are part of a "larger common plan of development or sale" that is greater than one acre, or (c) less than one acre, but determined to pose a risk to water quality are regulated under the state's NPDES/SDS Construction Stormwater General Permit (MNR100001). This permit requires and identifies BMPs to be implemented to protect water resources from mobilized sediment and other pollutants of concern. If the owner/operator of impacted construction sites obtain and abide by the NPDES/SDS Construction Stormwater General Permit, the stormwater discharges associated with those sites are expected to meet the WLAs set in this TMDL report.

Similar to construction activities, industrial sites are regulated under general permits, in this case either the NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or the NPDES/SDS

Nonmetallic Mining/Associated Activities General Permit (MNG490000). Like the NPDES/SDS Construction Stormwater General Permit, these permits identify BMPs to be implemented to protect water resources from pollutant discharges at the site. If the owner/operator of industrial sites abide by the necessary NPDES/SDS Stormwater General Permits, the discharges associated with those sites are expected to meet the WLAs set in this TMDL report.

According to MPCA construction stormwater permit data, an average of 0.3% of the entire OTRW area was covered under the NPDES/SDS Construction Stormwater General Permit per year over the last five years (MPCA 2020m). Furthermore, there are currently no NPDES/SDS permitted industrial stormwater facilities in the drainage area of any of the impaired lakes covered in this TMDL report. Therefore, to calculate the WLA for construction and industrial stormwater, this TMDL report assumes that 0.3% of the applicable loading capacity for each lake is assigned to the construction/industrial stormwater WLA.

Animal Feedlots

NPDES and SDS permitted feedlot facilities and CAFOs not requiring permits are assigned a WLA of zero. This is consistent with the conditions of the permits and the design and operation standards and requirements for CAFOs in Minnesota, which allow no pollutant discharge from the livestock housing facilities and associated manure storage areas. Furthermore, there are currently no CAFO feedlots within the drainage areas of any impaired lake addressed in this TMDL report. Therefore, no CAFO feedlots were assigned a TP WLA. Discharge of P-carrying sediment or manure from non-CAFO feedlots and fields where manure has been stockpiled or land-applied may occur during runoff events, but those discharges are covered under the LA portion of the TMDL and do not require an additional WLA.

4.4.4 Margin of safety

The MOS accounts for uncertainty in the lake models, observed water quality data, and the HSPF model. An explicit 15% MOS is used for all lakes with an "additional" internal loading allocation, or all lakes except for Johnson Lake. For Johnson Lake, an explicit 10% MOS is used to quantify the uncertainty. The explicit 15% MOS covers the uncertainty of the HPSF model (see additional description in **Sections 4.2.5** and **4.3.4**) and uncertainty in the internal loading rates used to calibrate the BATHTUB models. Since Johnson Lake did not need an "additional" internal load and any internal loading is implicitly included in the BATHTUB lake model equations, a 10% MOS is used since there would be less uncertainty in the BATHTUB model estimates, since 10% is a good representation of uncertainty of the HSPF model (see **Sections 4.2.5** and **4.3.4**), and since 10% was determined to be sufficient and reasonable.

4.4.5 Seasonal variation and critical conditions

Lakes are generally not sensitive to short term changes in water quality but rather respond to long-term changes and variation in seasonal and/or annual loads. Water quality monitoring suggests in-lake water quality varies over the course of the growing season, and generally in-lake nutrient concentrations peak in mid to late summer. The applicable water quality standards apply from June through September and MPCA guidelines for assessing lake TP is defined as the June through September mean concentration. The BATHTUB models were used to calculate the load capacities for each lake, incorporating mean growing season TP values and seasonal or annual loads, depending on the hydrologic residence time of the lake. Calibration to the summer critical period provides adequate protection during times of the year with reduced loading.

4.4.6 TMDL summary

The allowable TP load, or loading capacity, for each lake was divided among the WLA, LA, and the MOS as described in the above sections. The following tables summarize the existing and allowable TP loads (Total Load (lbs/yr) and Loading Capacity (lbs/day), respectively), the TMDL WLAs and LAs, and estimated required reductions for each lake. It should be noted that some of the numbers in the tables show multiple digits; they are not intended to imply great precision, but rather, this is done primarily to make the arithmetic accurate.

For lake P, the overall estimated percent reduction is the reduction of the existing condition to meet the applicable 60 µg/L standard for shallow lakes in the NCHF ecoregion. The estimated percent reductions provide a rough approximation of the overall reduction needed for the waterbody to meet the TMDL. The percent reduction is a means to capture the level of effort needed to reduce P concentrations in the watershed. The percent reductions should not be construed to mean that each of the separate sources listed in the TMDL table needs to be reduced by that amount.

The overall estimated percent reduction was applied for each impaired lake to NPS and internal loading allocations in the following order, until the overall load reduction was met:

1. NPS loads were reduced to the P component of the CRNR river eutrophication standards (100 µg/L);
2. Internal loading was reduced up to 95% of the total estimated internal load;
3. NPS loads were reduced further until overall load reductions were met, if needed.

Load reductions were applied in the above order to ensure that reductions were reasonable, realistic, and usable. This method limits the NPS load reduction, first, to what would be needed in a river or stream to meet water quality standards and then allows some internal loading to remain, since it is assumed it would be near impossible to entirely remove internal loading from some or all of the impaired lakes. If the overall reduction is not met after steps one and two, then additional NPS reductions would be needed. This method promotes NPS reductions occurring first, and does not prohibit additional NPS reductions in step one or prevent NPS reductions from continuing to occur simultaneously with internal loading reductions. Finally, using the CRNR P standard for the overland flow or NPS reductions does not imply that any tributaries flowing into the lakes are impaired due to P or fail to meet river eutrophication standards, or even that the NPS loading is coming from tributary streams. It is only used as a metric to determine a reasonable loading condition to determine the first step NPS load reduction.

It should be noted that the overall load reductions and the reductions for the total LAs are different. This is due to the MOS not being included in the existing loads and atmospheric deposition being held constant when applying the load reductions.

Baseline years for each TMDL are included in the header for each TMDL table. The baseline year is the year used to provide a reasonable condition for tracking reductions. The baseline year is taken as the year with observed data closest to the median in-lake condition.

Table 33. TP TMDL for Wine Lake (03-0398-00).

Phosphorus Listing year: 2012 Baseline year: 2008 Numeric WQ standard used: 60 µg/L		**Existing Phosphorus Load**		**Allowable Phosphorus Load**		**Estimated Load Reduction**	
		lbs/yr	**lbs/day**	**lbs/yr**	**lbs/day**	**lbs/yr**	**%**
Wasteload Allocation	**Total WLA**	**0.11**	**0.0003**	**0.11**	**0.0003**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.11	0.0003	0.11	0.0003	0	0%
Load Allocation	**Total LA**	**78.22**	**0.2143**	**31.26**	**0.0856**	**46.96**	**60%**
	Nonpoint Sources	29.72	0.0815	21.92	0.0601	7.80	26%
	Internal Loading/ Unknown Sources[2]	41.23	0.1129	2.07	0.0056	39.16	95%
	Atmospheric deposition	7.27	0.0199	7.27	0.0199	0	0%
Margin of Safety (MOS)[3]				**5.54**	**0.0152**		
Total Load/Loading Capacity		**78.33**	**0.2146**	**36.91**	**0.1011**	**41.42**	**53%**

[1]Assumes 0.3% of Allowable Loading Capacity. Assumes existing permits are being met with current BMPs.
[2]Internal loading includes any unknown sources not accounted for in the nonpoint sources and lake models.
[3]Margin of Safety is 15% of loading capacity.

Table 34. TP TMDL for Long Lake (56-0210-00).

Phosphorus Listing year: 2020 Baseline year: 2016 Numeric WQ standard used: 60 µg/L		**Existing Phosphorus Load**		**Allowable Phosphorus Load**		**Estimated Load Reduction**	
		lbs/yr	**lbs/day**	**lbs/yr**	**lbs/day**	**lbs/yr**	**%**
Wasteload Allocation	**Total WLA**	**3.43**	**0.009**	**3.43**	**0.009**	**0**	**0%**
	Construction/Industrial Stormwater[1]	3.43	0.009	3.43	0.009	0	0%
Load Allocation	**Total LA**	**4,290.24**	**11.753**	**968.01**	**2.652**	**3,322.23**	**77%**
	Nonpoint Sources	325.68	0.892	298.20	0.817	27.48	8%
	Internal Loading/ Unknown Sources[2]	3,710.38	10.165	415.63	1.139	3,294.75	89%
	Atmospheric deposition	254.18	0.696	254.18	0.696	0	0%
Margin of Safety (MOS)[3]				**171.43**	**0.470**		
Total Load/Loading Capacity		**4,293.67**	**11.762**	**1,142.87**	**3.131**	**3,150.80**	**73%**

[1]Assumes 0.3% of Allowable Loading Capacity. Assumes existing permits are being met with current BMPs.
[2]Internal loading includes any unknown sources not accounted for in the nonpoint sources and lake models.
[3]Margin of Safety is 15% of loading capacity.

Table 35. TP TMDL for Crooked Lake (56-0458-00).

Phosphorus Listing year: 2020 Baseline year: 2012 Numeric WQ standard used: 60 µg/L		Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Wasteload Allocation	**Total WLA**	**0.86**	**0.002**	**0.86**	**0.002**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.86	0.002	0.86	0.002	0	0%
Load Allocation	**Total LA**	**467.49**	**1.281**	**242.49**	**0.664**	**225.00**	**48%**
	Nonpoint Sources	209.71	0.575	144.62	0.396	65.09	31%
	Internal Loading/ Unknown Sources[2]	227.08	0.622	67.17	0.184	159.91	70%
	Atmospheric deposition	30.70	0.084	30.70	0.084	0	0%
Margin of Safety (MOS)[3]				**42.94**	**0.118**		
Total Load/Loading Capacity		**468.35**	**1.283**	**286.29**	**0.784**	**182.06**	**39%**

[1]Assumes 0.3% of Allowable Loading Capacity. Assumes existing permits are being met with current BMPs.
[2]Internal loading includes any unknown sources not accounted for in the nonpoint sources and lake models.
[3]Margin of Safety is 15% of loading capacity.

Table 36. TP TMDL for West Spirit Lake (56-0502-00).

Phosphorus Listing year: 2008 Baseline year: 2007 Numeric WQ standard used: 60 µg/L		Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Wasteload Allocation	**Total WLA**	**0.92**	**0.003**	**0.92**	**0.003**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.92	0.003	0.92	0.003	0	0%
Load Allocation	**Total LA**	**424.85**	**1.164**	**260.78**	**0.714**	**164.07**	**39%**
	Nonpoint Sources	42.20	0.116	42.20	0.116	0.00	0%
	Internal Loading/ Unknown Sources[2]	321.87	0.882	157.80	0.432	164.07	51%
	Atmospheric deposition	60.78	0.166	60.78	0.166	0	0%
Margin of Safety (MOS)[3]				**46.18**	**0.127**		
Total Load/Loading Capacity		**425.77**	**1.167**	**307.88**	**0.844**	**117.89**	**28%**

[1]Assumes 0.3% of Allowable Loading Capacity. Assumes existing permits are being met with current BMPs.
[2]Internal loading includes any unknown sources not accounted for in the nonpoint sources and lake models.
[3]Margin of Safety is 15% of loading capacity.

Table 37. TP TMDL for Norway Lake (East Bay) (56-0569-01).

Phosphorus Listing year: 2020 Baseline year: 2012 Numeric WQ standard used: 60 µg/L		Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Wasteload Allocation	**Total WLA**	**1.10**	**0.003**	**1.10**	**0.003**	**0**	**0%**
	Construction/Industrial Stormwater[1]	1.10	0.003	1.10	0.003	0	0%
Load Allocation	**Total LA**	**1,505.79**	**4.125**	**309.67**	**0.848**	**1,196.12**	**79%**
	Nonpoint Sources	118.71	0.325	79.81	0.219	38.90	33%
	Internal Loading/ Unknown Sources[2]	1,313.96	3.600	156.74	0.429	1,157.22	88%
	Atmospheric deposition	73.12	0.200	73.12	0.200	0	0%
Margin of Safety (MOS)[3]				**54.84**	**0.150**		
Total Load/Loading Capacity		**1,506.89**	**4.128**	**365.61**	**1.001**	**1,141.28**	**76%**

[1]Assumes 0.3% of Allowable Loading Capacity. Assumes existing permits are being met with current BMPs.
[2]Internal loading includes any unknown sources not accounted for in the nonpoint sources and lake models.
[3]Margin of Safety is 15% of loading capacity.

Table 38. TP TMDL for Norway Lake (West Bay) (56-0569-02).

Phosphorus Listing year: 2020 Baseline year: 2012 Numeric WQ standard used: 60 µg/L		Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Wasteload Allocation	**Total WLA**	**0.96**	**0.003**	**0.96**	**0.003**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.96	0.003	0.96	0.003	0	0%
Load Allocation	**Total LA**	**1,227.75**	**3.364**	**270.87**	**0.742**	**956.88**	**78%**
	Nonpoint Sources	405.82	1.112	209.20	0.573	196.62	48%
	Internal Loading/ Unknown Sources[2]	800.27	2.193	40.01	0.110	760.26	95%
	Atmospheric deposition	21.66	0.059	21.66	0.059	0	0%
Margin of Safety (MOS)[3]				**47.97**	**0.131**		
Total Load/Loading Capacity		**1,228.71**	**3.367**	**319.80**	**0.876**	**908.91**	**74%**

[1]Assumes 0.3% of Allowable Loading Capacity. Assumes existing permits are being met with current BMPs.
[2]Internal loading includes any unknown sources not accounted for in the nonpoint sources and lake models.
[3]Margin of Safety is 15% of loading capacity.

Table 39. TP TMDL for Unnamed Lake (56-0791-00).

Phosphorus Listing year: 2020 Baseline year: 2012 Numeric WQ standard used: 60 µg/L		**Existing Phosphorus Load**		**Allowable Phosphorus Load**		**Estimated Load Reduction**	
		lbs/yr	**lbs/day**	**lbs/yr**	**lbs/day**	**lbs/yr**	**%**
Wasteload Allocation	**Total WLA**	**0.45**	**0.001**	**0.45**	**0.001**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.45	0.001	0.45	0.001	0	0%
Load Allocation	**Total LA**	**1,068.74**	**2.928**	**125.91**	**0.345**	**942.83**	**88%**
	Nonpoint Sources	227.08	0.622	52.90	0.145	174.18	77%
	Internal Loading/ Unknown Sources[2]	809.10	2.217	40.45	0.111	768.65	95%
	Atmospheric deposition	32.56	0.089	32.56	0.089	0	0%
Margin of Safety (MOS)[3]				**22.30**	**0.061**		
Total Load/Loading Capacity		**1,069.19**	**2.929**	**148.66**	**0.407**	**920.53**	**86%**

[1]Assumes 0.3% of Allowable Loading Capacity. Assumes existing permits are being met with current BMPs.
[2]Internal loading includes any unknown sources not accounted for in the nonpoint sources and lake models.
[3]Margin of Safety is 15% of loading capacity.

Table 40. TP TMDL for Devils Lake (56-0882-00).

Phosphorus Listing year: 2020 Baseline year: 2012 Numeric WQ standard used: 60 µg/L		**Existing Phosphorus Load**		**Allowable Phosphorus Load**		**Estimated Load Reduction**	
		lbs/yr	**lbs/day**	**lbs/yr**	**lbs/day**	**lbs/yr**	**%**
Wasteload Allocation	**Total WLA**	**1.50**	**0.004**	**1.50**	**0.004**	**0**	**0%**
	Construction/Industrial Stormwater[1]	1.50	0.004	1.50	0.004	0	0%
Load Allocation	**Total LA**	**1,146.60**	**3.142**	**424.52**	**1.164**	**722.08**	**63%**
	Nonpoint Sources	274.59	0.752	207.92	0.570	66.67	24%
	Internal Loading/ Unknown Sources[2]	800.28	2.193	144.87	0.397	655.41	82%
	Atmospheric deposition	71.73	0.197	71.73	0.197	0	0%
Margin of Safety (MOS)[3]				**75.18**	**0.206**		
Total Load/Loading Capacity		**1,148.10**	**3.146**	**501.20**	**1.374**	**646.90**	**56%**

[1]Assumes 0.3% of Allowable Loading Capacity. Assumes existing permits are being met with current BMPs.
[2]Internal loading includes any unknown sources not accounted for in the nonpoint sources and lake models.
[3]Margin of Safety is 15% of loading capacity.

Table 41. TP TMDL for Grandrud Lake (56-0907-00).

Phosphorus Listing year: 2020 Baseline year: 2012 Numeric WQ standard used: 60 µg/L		Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	**lbs/day**	**lbs/yr**	**lbs/day**	**lbs/yr**	**%**
Wasteload Allocation	**Total WLA**	**0.60**	**0.002**	**0.60**	**0.002**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.60	0.002	0.60	0.002	0	0%
Load Allocation	**Total LA**	**209.22**	**0.573**	**170.73**	**0.468**	**38.49**	**18%**
	Nonpoint Sources	67.13	0.184	67.13	0.184	0.00	0%
	Internal Loading/ Unknown Sources[2]	115.74	0.317	77.25	0.212	38.49	33%
	Atmospheric deposition	26.35	0.072	26.35	0.072	0	0%
Margin of Safety (MOS)[3]				**30.24**	**0.083**		
Total Load/Loading Capacity		**209.82**	**0.575**	**201.57**	**0.553**	**8.25**	**4%**

[1]Assumes 0.3% of Allowable Loading Capacity. Assumes existing permits are being met with current BMPs.
[2]Internal loading includes any unknown sources not accounted for in the nonpoint sources and lake models.
[3]Margin of Safety is 15% of loading capacity.

Table 42. TP TMDL for Johnson Lake (56-0979-00).

Phosphorus Listing year: 2020 Baseline year: 2012 Numeric WQ standard used: 60 µg/L		Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	**lbs/day**	**lbs/yr**	**lbs/day**	**lbs/yr**	**%**
Wasteload Allocation	**Total WLA**	**0.50**	**0.001**	**0.50**	**0.001**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.50	0.001	0.50	0.001	0	0%
Load Allocation	**Total LA**[2]	**332.71**	**0.911**	**150.86**	**0.413**	**181.85**	**55%**
	Nonpoint Sources	296.85	0.813	115.00	0.315	181.85	61%
	Atmospheric deposition	35.86	0.098	35.86	0.098	0	0%
Margin of Safety (MOS)[3]				**16.82**	**0.046**		
Total Load/Loading Capacity		**333.21**	**0.912**	**168.18**	**0.460**	**165.03**	**50%**

[1]Assumes 0.3% of Allowable Loading Capacity. Assumes existing permits are being met with current BMPs.
[2]No “additional” internal loading needed, any internal loading is implied in BATHTUB lake model equations.
[3]Margin of Safety is 10% of loading capacity.

Table 43. TP TMDL for Oscar Lake (56-0982-00).

Phosphorus Listing year: 2020 Baseline year: 2008 Numeric WQ standard used: 60 µg/L		Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Wasteload Allocation	**Total WLA**	**3.27**	**0.009**	**3.27**	**0.009**	**0**	**0%**
	Construction/Industrial Stormwater[1]	3.27	0.009	3.27	0.009	0	0%
Load Allocation	**Total LA**	**3,484.10**	**9.546**	**923.98**	**2.531**	**2,560.12**	**73%**
	Nonpoint Sources	2,082.91	5.707	779.42	2.135	1,303.49	63%
	Internal Loading/ Unknown Sources[2]	1,322.77	3.624	66.14	0.181	1,256.63	95%
	Atmospheric deposition	78.42	0.215	78.42	0.215	0	0%
Margin of Safety (MOS)[3]				**163.63**	**0.448**		
Total Load/Loading Capacity		**3,487.37**	**9.555**	**1,090.88**	**2.988**	**2,396.49**	**69%**

[1]Assumes 0.3% of Allowable Loading Capacity. Assumes existing permits are being met with current BMPs.
[2]Internal loading includes any unknown sources not accounted for in the nonpoint sources and lake models.
[3]Margin of Safety is 15% of loading capacity.

Table 44. TP TMDL for Hovland Lake (56-1014-00).

Phosphorus Listing year: 2020 Baseline year: 2012 Numeric WQ standard used: 60 µg/L		Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Wasteload Allocation	**Total WLA**	**1.38**	**0.004**	**1.38**	**0.004**	**0**	**0%**
	Construction/Industrial Stormwater[1]	1.38	0.004	1.38	0.004	0	0%
Load Allocation	**Total LA**	**2,585.48**	**7.083**	**389.16**	**1.066**	**2,196.32**	**85%**
	Nonpoint Sources	495.27	1.357	244.64	0.670	250.63	51%
	Internal Loading/ Unknown Sources[2]	2,048.09	5.611	102.40	0.281	1,945.69	95%
	Atmospheric deposition	42.12	0.115	42.12	0.115	0	0%
Margin of Safety (MOS)[3]				**68.92**	**0.189**		
Total Load/Loading Capacity		**2,586.86**	**7.087**	**459.46**	**1.259**	**2,127.40**	**82%**

[1]Assumes 0.3% of Allowable Loading Capacity. Assumes existing permits are being met with current BMPs.
[2]Internal loading includes any unknown sources not accounted for in the nonpoint sources and lake models.
[3]Margin of Safety is 15% of loading capacity.

Table 45. TP TMDL for Twin Lake (56-1525-00).

Phosphorus Listing year: 2020 Baseline year: 2012 Numeric WQ standard used: 60 µg/L		Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	**lbs/day**	**lbs/yr**	**lbs/day**	**lbs/yr**	**%**
Wasteload Allocation	**Total WLA**	**0.61**	**0.002**	**0.61**	**0.002**	**0**	**0%**
	Construction/Industrial Stormwater[1]	0.61	0.002	0.61	0.002	0	0%
Load Allocation	**Total LA**	**805.32**	**2.206**	**172.81**	**0.473**	**632.51**	**79%**
	Nonpoint Sources[4]	155.86	0.427	97.97	0.268	57.89	37%
	Internal Loading/ Unknown Sources[2]	607.37	1.664	32.75	0.090	574.62	95%
	Atmospheric deposition	42.09	0.115	42.09	0.115	0	0%
Margin of Safety (MOS)[3]				**30.60**	**0.084**		
Total Load/Loading Capacity		**805.93**	**2.208**	**204.02**	**0.559**	**601.91**	**75%**

[1]Assumes 0.3% of Allowable Loading Capacity. Assumes existing permits are being met with current BMPs.
[2]Internal loading includes any unknown sources not accounted for in the nonpoint sources and lake models.
[3]Margin of Safety is 15% of loading capacity.

5. Future growth considerations

Potential changes in population and land use/land cover over time in the OTRW could result in changing sources of pollutants. According to the Minnesota State Demographic Center (Admin 2020), over the period from 2015 to 2035, the populations in the OTRW are projected to increase in all counties (Becker 12%, Clay 20%, Clearwater 2%, Mahnomen 2.4%, and Otter Tail 4.5%), except for Wilkin (-18%), with an overall growth of 10.4% in the six counties. However, it is important to note that most or even all of the growth in Clay, Clearwater, and Mahnomen counties will occur outside of the OTRW, as these counties include just small portions of the OTRW. Much of the growth in Becker and Otter Tail counties will likely occur within the OTRW, especially within and near cities and areas close to popular recreational lakes, such as Detroit Lakes, Frazee, Pelican Rapids, Fergus Falls, and Perham.

While city populations may continue to increase, much of the relevant growth is expected to occur surrounding the many lakes in the watershed. This includes the transition of seasonal cabins and lakeshore properties into year-round homes, additional development of lakeshores with little development, “second-tier” development away from the immediate lakeshores of highly populated lakes, and the creation or expansion of recreational properties such as RV or trailer campgrounds. This increased development may further tax the waterbodies in the OTRW as impervious surface area and runoff increase in lakesheds.

5.1 New or expanding permitted MS4 WLA transfer process

Future transfer of watershed runoff loads in this TMDL may be necessary if any of the following scenarios occur within the project watershed boundaries.

1. New development occurs within a permitted MS4. Newly developed areas that are not already included in the WLA must be transferred from the LA to the WLA to account for the growth.
2. One permitted MS4 acquires land from another permitted MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more nonpermitted MS4s become permitted. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of a U.S. Census Bureau Urban Area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an urban area at the time the TMDL was completed but are now inside a newly expanded urban area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other stormwater-related point source is identified and is covered under an NPDES permit. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL report. In cases where WLA is transferred from or to a permitted MS4, the permittees will be notified of the transfer and have an opportunity to comment.

5.2 New or expanding wastewater (TSS and *E. coli* TMDLs only)

The MPCA, in coordination with the EPA Region 5, has developed a streamlined process for setting or revising WLAs for new or expanding wastewater discharges to waterbodies with an EPA approved TMDL for TSS or *E. coli* (described in MPCA 2012). This procedure will be used to update WLAs in approved TMDLs for new or expanding wastewater dischargers whose permitted effluent limits are at or below the instream target and will ensure that the effluent concentrations will not exceed applicable water quality standards or surrogate measures. The process for modifying any and all WLAs will be handled by the MPCA, with input and involvement by the EPA, once a permit request or reissuance is submitted. The overall process will use the permitting public notice process to allow for the public and EPA to comment on the permit changes based on the proposed WLA modification(s). Once any comments or concerns are addressed, and the MPCA determines that the new or expanded wastewater discharge is consistent with the applicable water quality standards, the permit will be issued and any updates to the TMDL WLA(s) will be made.

6. Reasonable assurance

A TMDL report needs to provide reasonable assurance that water quality targets will be achieved through the specified combination of point and nonpoint source reductions reflected in the LAs and WLAs. According to EPA guidance (EPA 2002), "When a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint source load reductions will occur... the TMDL should provide reasonable assurances that nonpoint source control measures will achieve expected load reductions in order for the TMDL to be approvable. This information is necessary for the EPA to determine that the TMDL, including the LA and WLAs, has been established at a level necessary to achieve water quality standards." In the OTRW, considerable reductions in NPS are required.

The MPCA will:

- Evaluate existing programmatic, funding, and technical capacity to implement basin and watershed strategies.
- Identify gaps in current programs, funding, and local capacity to achieve the needed controls.
- Build program capacity for short-term and long-term goals. Demonstrate increased implementation and/or pollutant reductions.
- Commit to track/monitor/assess and report progress at set regular times.

6.1 Reduction of permitted sources

6.1.1 Permitted construction stormwater

Regulated construction stormwater was given a categorical WLA is this study. Construction activities disturbing one acre or more are required to obtain NPDES/SDS permit coverage through the MPCA. Compliance with TMDL requirements are assumed when a construction site owner/operator meets the conditions of the Construction General Permit and properly selects, installs, and maintains all BMPs required under the permit, including any applicable additional BMPs required in Section 23 of the

Construction General Permit for discharges to impaired waters, or compliance with local construction stormwater requirements if they are more restrictive than those in the State General Permit.

6.1.2 Permitted industrial stormwater

Industrial stormwater was given a categorical WLA in this study. Industrial activities require permit coverage under the state's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS Nonmetallic Mining/Associated Activities General Permit (MNG490000). If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS permit and properly selects, installs, and maintains BMPs sufficient to meet the benchmark values in the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL report.

6.1.3 Municipal Separate Storm Sewer System Permits

The MPCA is responsible for applying federal and state regulations to protect and enhance water quality in Minnesota. The MPCA oversees stormwater management accounting activities for all MS4 entities listed in this TMDL report. The Small MS4 General Permit requires regulated municipalities to implement BMPs that reduce pollutants in stormwater to the maximum extent practicable. A critical component of permit compliance is the requirement for the owners or operators of a permitted MS4 conveyance to develop a SWPPP. The SWPPP addresses all permit requirements, including the following six measures:

- Public education and outreach;
- Public participation;
- Illicit discharge detection and elimination program;
- Construction site runoff controls;
- Post-construction runoff controls; and
- Pollution prevention and municipal good housekeeping measures.

A SWPPP is a management plan that describes the MS4 permittee’s activities for managing stormwater within their regulated area. In the event of a completed TMDL study, MS4 permittees must document the WLA in their future NPDES/SDS permit application and provide an outline of the BMPs to be implemented that address needed reductions. The MPCA requires MS4 owners or operators to submit their application and corresponding SWPPP document to the MPCA for review. Once the application and SWPPP are deemed adequate by the MPCA, all application materials are placed on 30-day public notice, allowing the public an opportunity to review and comment on the prospective program. Once NPDES/SDS permit coverage is granted, permittees must implement the activities described within their SWPPP and submit an annual report to the MPCA documenting the implementation activities completed within the previous year, along with an estimate of the cumulative pollutant reduction achieved by those activities. For information on all requirements for annual reporting, please see the Minnesota Stormwater Manual (Minnesota Stormwater Manual contributors 2019): Guidance for completing the TMDL reporting form.

This TMDL report assigns WLAs to permitted MS4s in the study area. The Small MS4 General Permit requires permittees to develop compliance schedules for EPA approved TMDL WLAs not already being met at the time of permit application. A compliance schedule includes BMPs that will be implemented over the permit term, a timeline for their implementation, and a long-term strategy for continuing progress towards assigned WLAs. For WLAs being met at the time of permit application, the same level of treatment must be maintained in the future. Regardless of WLA attainment, all permitted MS4s are still required to reduce pollutant loadings to the maximum extent practicable.

The MPCA's stormwater program and its NPDES permit program are regulatory activities providing reasonable assurance that implementation activities are initiated, maintained, and consistent with WLAs assigned in this study.

6.1.4 Permitted wastewater

All currently existing and future domestic and industrial wastewater NPDES/SDS permits in the watershed will reflect limits consistent with WLAs described herein. Discharge monitoring is conducted by permittees and routinely submitted to the MPCA for review.

NPDES/SDS permits for discharges that may cause or have reasonable potential to cause or contribute to an exceedance of a water quality standard are required to contain water quality based effluent limits (WQBELs) consistent with the assumptions and requirements of the WLAs in this TMDL report. Attaining the WLAs, as developed and presented in this TMDL report, is assumed to ensure meeting the water quality standards for the relevant impaired waters listings. During the permit issuance or reissuance process, wastewater discharges will be evaluated for the potential to cause or contribute to violations of water quality standards. WQBELs will be developed for facilities whose discharges are found to have a reasonable potential to cause or contribute to exceedances of applicable water quality standards. The WQBELs will be calculated based on low flow conditions, may vary slightly from the TMDL WLAs, and will include concentration based effluent limitations.

According to the MPCA, since 2006, wastewater improvements in the OTRW have reduced P by 90% and TSS by 67%. The oxygen demand (CBOD) has increased by 24% (MPCA 2020e). Significant P reductions have been documented at the Pelican Rapids WWTP since 2009, while significant TSS reductions were documented at the Fergus Falls WWTP starting in 2007. Increases in CBOD have been reported at the Detroit Lakes WWTP from 2017 through 2019, potentially due to the transition from the previous facility to the newly constructed WWTP completed in 2019.

6.1.5 Permitted feedlots

See the discussion of the state's Feedlot Program in **Section 6.2.2**, which applies to both permitted and nonpermitted feedlots.

6.2 Reduction of nonpermitted sources

Several nonpermitted reduction programs exist to support implementation of NPS reduction BMPs in the OTRW. These programs identify BMPs, provide means of focusing BMPs, and support their implementation via state initiatives, ordinances, and/or dedicated funding. According to the MPCA's Healthier Watersheds website and data from local partners, over 3,500 BMP and capital improvement projects (see **Figure 24**) were implemented in the OTRW between 2004 and 2019 (MPCA 2020f and PRWD 2020).

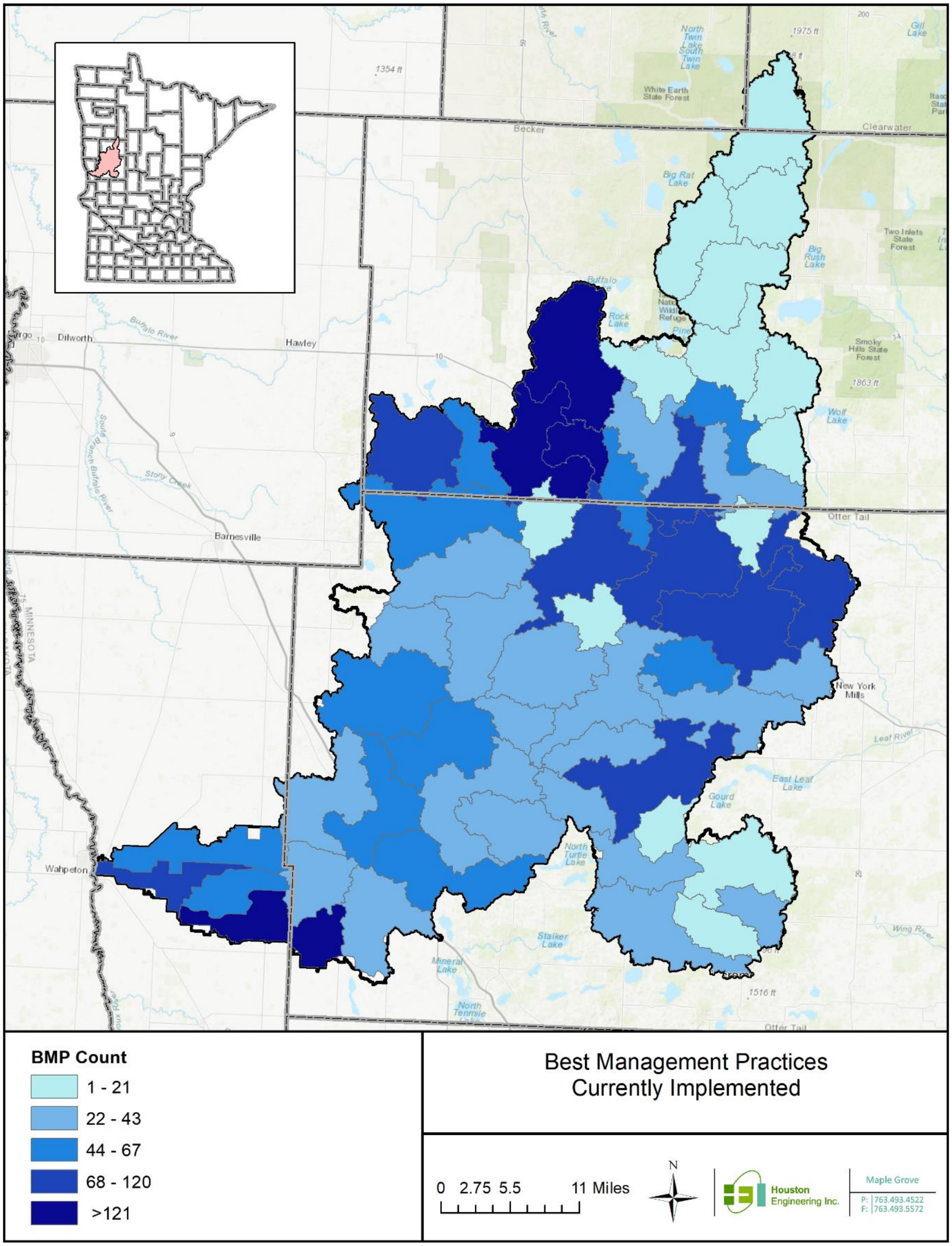


Figure 24. Number of BMPs per subwatershed in the OTRW between 2004-2019 (MPCA 2020f and PRWD 2020).

Many SWCDs, WDs, lake associations, and other organizations are active in the OTRW, and some provide technical and financial assistance on topics such as nutrient management, drainage, and other agricultural BMPs, septic system improvements, lakeshore restorations, urban stormwater runoff management, and more. The work of these organizations is significant in the OTRW for implementing BMPs and achieving NPS reductions.

The following examples describe large-scale programs that have proven to be effective and/or will reduce pollutant loads going forward.

6.2.1 Subsurface Sewage Treatment Systems Program

SSTS are regulated through Minn. Stat. §§ 115.55 and 115.56. SSTS specific rule requirements can be found in Minn. R. 7080 through 7083. Regulations include the following:

- Minimum technical standards for design and installation of individual and mid-size SSTS;
- A framework for local units of government to administer SSTS programs;
- Statewide licensing and certification of SSTS professionals, SSTS product review and registration, and establishment of the SSTS Advisory Committee; and
- Various ordinances for SSTS installation, maintenance, and inspection.

Each county maintains an SSTS ordinance, in accordance with Minn. Stat. and Minn. R., establishing minimum requirements for regulation of SSTS, for the treatment and dispersal of sewage within the applicable jurisdiction of the county, to protect public health and safety, to protect groundwater quality, and to prevent or eliminate the development of public nuisances. Ordinances serve the best interests of the county's citizens by protecting health, safety, general welfare, and natural resources. In addition, each county zoning ordinance prescribes the technical standards that on-site septic systems are required to meet for compliance and outlines the requirements for the upgrade of systems found not to be in compliance. This includes systems subject to inspection at transfer of property, upon the addition of living space that includes a bedroom and/or a bathroom, and at discovery of the failure of an existing system. From 2002 through 2016, the three counties making up the majority of the OTRW, Becker, Otter Tail and Wilkin counties, have, on average, replaced 107 systems per year (**Figure 25**).

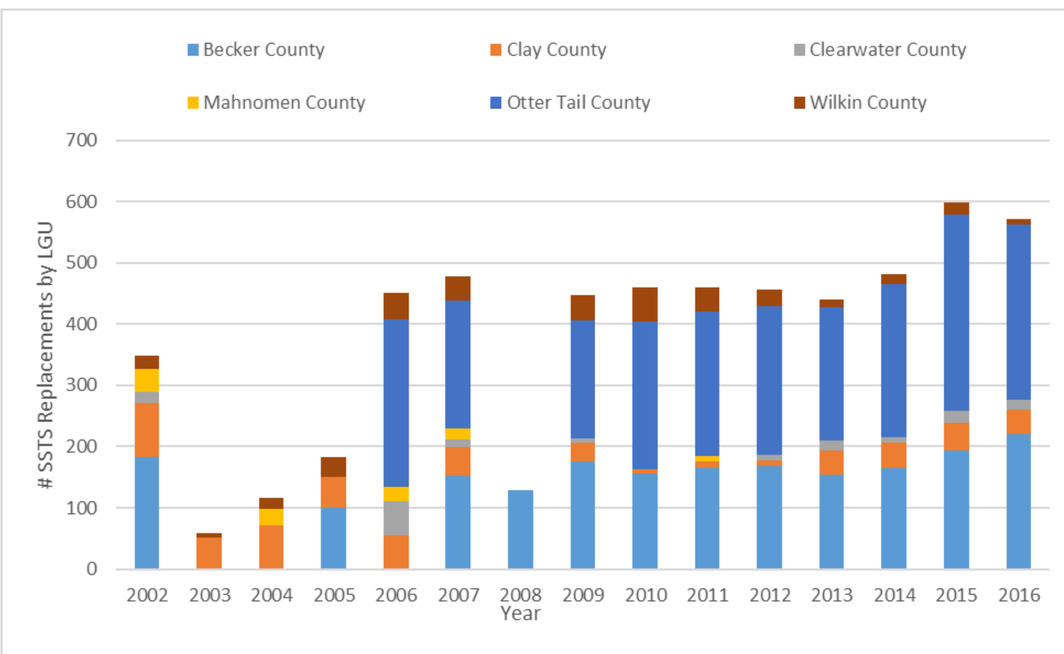


Figure 25. SSTS replacements by county for counties in the OTRW.

All known ITPHS are recorded in a statewide database by the MPCA. From 2006 to 2019, 797 alleged straight pipes were tracked by the MPCA statewide, 765 of which were abandoned, fixed, or were found not to be a straight pipe system. The remaining known, unfixed, straight pipe systems have received a notice of noncompliance and are currently within the 10-month deadline to be fixed, have been issued Administrative Penalty Orders, or are docketed in court.

The MPCA, through the Clean Water Partnership Loan Program, has recently approved up to $3 million in funding to Otter Tail County to provide zero interest loans for SSTS upgrades. This zero interest loan funding is available to county property owners and businesses through spring 2023. More information on Otter Tail County's zero interest loan program can be found here: https://ottertailcountymn.us/content-page/ssts-financial-assistance-loan/. More information on the MPCA's SSTS financial assistance can be found at the following address: https://www.pca.state.mn.us/water/ssts-financial-assistance. No other counties or local government units (LGU) in the OTRW have recently participated in the MPCA's Clean Water Partnership Loan Program for SSTS upgrades.

6.2.2 Feedlot Program

This section describes the MPCA's Feedlot Program, which addresses both permitted and nonpermitted feedlots. The Feedlot Program implements rules governing the collection, transportation, storage, processing, and disposal of animal manure and other livestock operation wastes. Minn. R. ch. 7020 regulates feedlots in the state of Minnesota. The focus of the rule is on animal feedlots and manure storage areas that have the greatest potential for environmental impact. A feedlot holding 1,000 or more AUs is permitted in Minnesota.

There are two primary concerns about feedlots in protecting water:

- Ensuring that manure on a feedlot or in a manure storage area does not run into water.
- Ensuring that manure is applied to cropland at a rate, time, and method that prevents fecal bacteria, nutrients and other possible contaminants from entering streams, lakes, and groundwater.

The Feedlot Program is implemented through cooperation between MPCA and delegated county governments in 50 counties in the state. The MPCA works with county representatives to provide training, program oversight, policy and technical support, and formal enforcement support when needed. A county participating in the program has been delegated authority by the MPCA to administer the Feedlot Program. These delegated counties receive state grants to help fund their feedlot programs based on the number of feedlots in the county and the level of inspections they complete. In recent years, annual grants given to these counties statewide totaled about two million dollars (MPCA 2017).

In the OTRW, Clay County is the only delegated county and the regulatory authority is delegated to the Clay SWCD. The Clay SWCD will continue to work with the MPCA to implement the feedlot program and work with producers on feedlot registrations and permits, compliance inspections, and manure management plans. In Clay County, all non-CAFO feedlots are inspected by the county feedlot officer on a routine basis in accordance with the county's Delegation Agreement and Work Plan, which is prepared with and approved by MPCA every-other year. Only one feedlot in Clay County is located in the OTRW, and it is not required to be registered (MPCA 2020d).

In the remaining undelegated counties in the OTRW, the MPCA is the feedlot regulatory authority, working to register and issue permits to feedlot operators and to conduct compliance inspections. CAFOs are inspected in all counties by the MPCA in accordance with the MPCA NPDES Compliance Monitoring Strategy approved by the EPA. All CAFOs (NPDES permitted, SDS permitted and not required to be permitted) are inspected by the MPCA on a routine basis with an appropriate mix of field inspections, offsite monitoring, and compliance assistance. Non-CAFOs in nondelegated counties are inspected by MPCA on an as-needed or complaint-driven basis.

Almost all (99%) of the feedlots within the OTRW are located in Becker and Otter Tail Counties. There are three feedlots in Wilkin County located within the OTRW and only one is required to be registered. There is one feedlot in Clay County in the OTRW, mentioned above, and no feedlots within the OTRW in Clearwater and Mahnomen Counties (MPCA 2020d). As such, many of the feedlots in the OTRW have never been inspected by the MPCA, or have only been inspected for construction or a permit, due to a complaint, or as prioritized by the MPCA in conjunction with the development of the OTRW WRAPS and TMDL reports.

From 2009 through 2019, there were approximately 128 feedlot facility inspections conducted by the MPCA in Becker and Otter Tail Counties, over half of which occurred in 2017, 2018, and 2019. Approximately 80 of those 128 feedlot facility inspections occurred within the OTRW, with 11 of those 80 inspections occurring at CAFO facilities. Approximately 50 of the 80 feedlot facility inspections within the OTRW occurred in 2017, 2018, and 2019, many of which were conducted at facilities in conjunction with the development of the OTRW WRAPS and TMDL reports. Additionally, within that same time period and in that same area of the OTRW, there have been an additional four manure application reviews with three of those inspections conducted at CAFO facilities (MPCA 2020h).

6.2.3 Minnesota Buffer Law

Minnesota's buffer law (Minn. Stat. § 103F.48) requires perennial vegetative buffers of up to 50 feet along lakes, rivers, and streams and buffers of 16.5 feet along ditches. These buffers help filter out P, N, and sediment. Alternative practices are allowed in place of a perennial buffer in some cases. Amendments enacted in 2017 clarify the application of the buffer requirement to public waters, provide additional statutory authority for alternative practices, address concerns over the potential spread of invasive species through buffer establishment, establish a riparian protection aid program to fund local government buffer law enforcement and implementation, and allowed landowners to be granted a compliance waiver until July 1, 2018, when they filed a compliance plan with the appropriate SWCD.

The Board of Water and Soil Resources (BWSR) provides oversight of the buffer program, which is primarily administered at the local level. Compliance with the buffer law ranges from 95% to 100% for all counties in the OTRW (BWSR 2020a).

6.2.4 Minnesota Agricultural Water Quality Certification Program

The Minnesota Agricultural Water Quality Certification Program (MAWQCP) is a voluntary opportunity for farmers and agricultural landowners to take the lead in implementing conservation practices that protect our water. Those who implement and maintain approved farm management practices will be certified and, in turn, obtain regulatory certainty for a period of 10 years.

Through this program, certified producers receive:

- Regulatory certainty: certified producers are deemed to be in compliance with any new water quality rules or laws during the period of certification;
- Recognition: certified producers may use their status to promote their business as protective of water quality; and
- Priority for technical assistance: producers seeking certification can obtain specially designated technical and financial assistance to implement practices that promote water quality.

Through this program, the public receives assurance that certified producers are using conservation practices to protect Minnesota's lakes, rivers, and streams. Since the start of the program in 2014, the program has achieved the following (estimates as of April 1, 2021):

- Enrolled over 734,000 acres;
- Included 1,038 producers;
- Added approximately 2,100 new conservation practices;
- Kept almost 39,000 tons of sediment out of Minnesota rivers per year;
- Saved over 112,000 tons of soil and over 49,000 pounds of P on farms per year; and
- Cut greenhouse gas emissions by more than 40,000 tons annually.

As of December 31, 2019, approximately 17,149 acres in the OTRW have been certified under the MAWQCP. Additional farms in the OTRW have been and continue to become certified in 2020 and 2021.

6.2.5 Section 319 Small Watershed Focus Program

The federal CWA Section 319 grant program provides funding to states to address NPS water pollution in watersheds. The MPCA has adopted a Section 319 Small Watersheds Focus Program to focus on geographically smaller and longer term watershed projects. The intent of the program is to make measurable progress for targeted waterbodies in the Section 319 focus watersheds, ultimately restoring impaired waters and preventing degradation of unimpaired waters. Successful restorations in the OTRW through this program would support the required pollutant reductions. In September 2020, the Pelican River Watershed District (PRWD) was selected by the MPCA as part of the Small Watersheds Focus Program "Group C." The PRWD has begun the planning process, and efforts will be focused on restoring the TSS-impaired Campbell Creek with funding and work expected to begin in federal fiscal year 2022. The MPCA's Small Watersheds Focus Program "Group D" will also be available to local watershed partners, with a request for applications expected in 2021 and funding eligibility expected to begin in federal fiscal year 2023.

A previous federal CWA Section 319 grant project was completed in the fall of 2019 for the Lower Otter Tail River, from JD 2 to the Bois de Sioux River (WIDs 09020103-504 and 09020103-502). The project included surveying, planning, and designing channel restorations for approximately 20 channelized river miles located between Orwell Dam and Breckenridge Lake. The focus of the project was to provide design work for future restoration projects that will improve water quality by reducing sediment associated with stream bank failure, erosion, and channelization, and to retain some of the river's natural flood reduction features (MPCA 2020i). According to the project's work plan, the final engineering report, detailed plans, and specifications will be used to direct future management, construction work, and conservation practices that will result in long-term water quality benefits to the Otter Tail River, the Red River of the North, and the communities downstream. The channel restoration and implementation of other sediment controls, which are recommended in the detailed engineering design report, would take place as part of separate projects. Some projects have already been completed in the project area, including the Wilkin SWCD's work to install 300 acres of vegetative buffers, as well as sediment controls on 40 miles of legal ditch systems within the contributing drainage area. Hydraulic modeling completed during project design work will inform the placement of additional vegetative buffers, and GIS terrain analysis will be used to prioritize locations for additional sediment control BMP installation along the river. Upon completion of restoration and construction work, the project's survey work will provide the baseline data necessary to evaluate the effectiveness of the channel restoration and BMP implementation, which can then be used to further evaluate the impacts of channelization on water quality and stream habitat.

6.2.6 Minnesota Nutrient Reduction Strategy

The Minnesota Nutrient Reduction Strategy (NRS; MPCA 2015a) guides activities that support N and P reductions in Minnesota waterbodies and those waterbodies downstream of the state (e.g., Lake Winnipeg, Lake Superior, and the Gulf of Mexico). The NRS was developed by an interagency coordination team with help from public input, and a five-year progress report and update was completed in August, 2020 (MPCA 2020n). Fundamental elements of the NRS include:

- Defining progress with clear goals;
- Building on current strategies and success;
- Prioritizing problems and solutions;
- Supporting local planning and implementation; and
- Improving tracking and accountability.

Included within the strategy discussion are alternatives and tools for consideration by drainage authorities and local resource managers, information on available tools and approaches for identifying areas of P and N loading and tracking efforts within a watershed, and additional research priorities. The NRS is focused on incremental progress and provides meaningful and achievable nutrient load reduction milestones that allow for better understanding of incremental and adaptive progress toward final goals. The original strategy had set a reduction of 10% for P and 13% for N in the Lake Winnipeg (Red River of the North) Basin relative to 2003 conditions (MPCA 2015a). The memorandum "Updating Nutrient Reduction Strategy to Strengthen Linkages with Watersheds and WRAPS" (LimnoTech 2020) calls for common percentage or "fair share" reductions across Minnesota's 80 major watersheds, which focus efforts on both local waterbodies and nutrient reductions downstream. The "fair share" reductions provided for the OTRW by the year 2040 are 20.7% for P and 29.7% for N. While these reduction goals may meet or exceed those required for impaired waterbodies addressed in this TMDL report, they may also be used as a watershed-wide target for protecting and enhancing those nearly impaired and other unimpaired waterbodies within the OTRW.

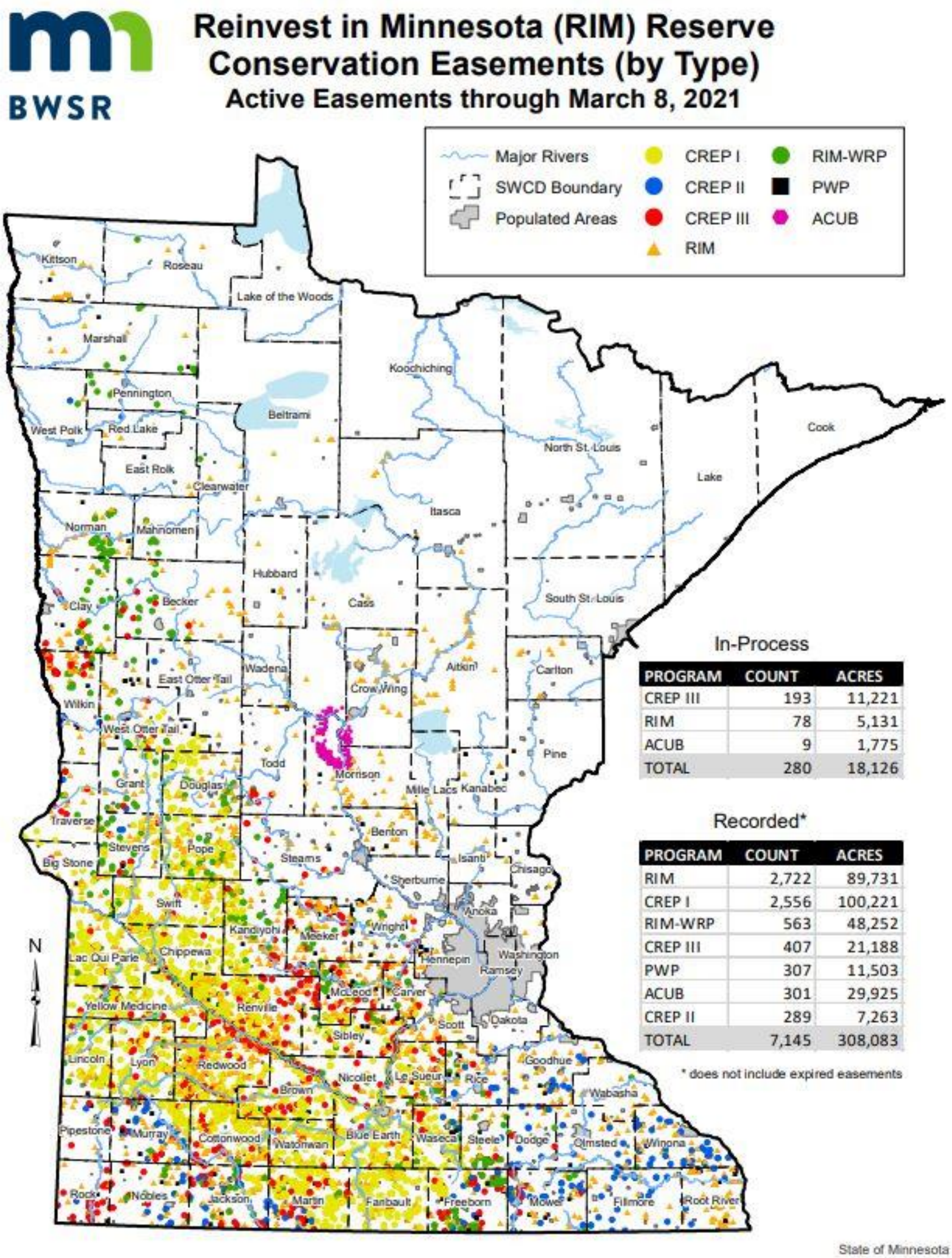
Successful implementation of the NRS will require broad support, coordination, and collaboration among agencies, academia, local government, and private industry. The MPCA is implementing a framework to integrate its water quality management programs on a major watershed scale, a process that includes:

- Intensive watershed monitoring;
- Assessment of watershed health;
- Development of WRAPS reports; and
- Management of NPDES and other regulatory and assistance programs.

This framework will result in nutrient reduction for the basin as a whole and the major watersheds within the basin.

6.2.7 Conservation easements

Conservation easements are a critical component of the state's efforts to improve water quality by reducing soil erosion, P and N loading, and improving wildlife habitat and flood attenuation on private lands. Easements protect the state's water and soil resources by permanently restoring wetlands, adjacent native grassland wildlife habitat complexes and permanent riparian buffers. In cooperation with county SWCDs and the USDA NRCS, the BWSR programs compensate landowners for granting conservation easements and establishing native vegetation habitat on economically marginal, flood-prone, environmentally sensitive or highly erodible lands. These easements vary in length of time from 10 years to permanent/perpetual easements. Types of conservation easements in Minnesota include Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP), Reinvest in Minnesota (RIM), and the Wetland Reserve Program (WRP) or Permanent Wetland Preserve (PWP), and are implemented throughout Minnesota (**Figure 26)**. As of August 2020, in the counties of Becker, Clay, Clearwater, Mahnomen, Otter Tail, and Wilkin, there were 104,294 acres of short-term conservation easements such as CRP and 33,122 acres of long term or permanent easements such as CREP, RIM, and WRP (BWSR 2020b).



In-Process

PROGRAM	COUNT	ACRES
CREP III	193	11,221
RIM	78	5,131
ACUB	9	1,775
TOTAL	280	18,126

Recorded*

PROGRAM	COUNT	ACRES
RIM	2,722	89,731
CREP I	2,556	100,221
RIM-WRP	563	48,252
CREP III	407	21,188
PWP	307	11,503
ACUB	301	29,925
CREP II	289	7,263
TOTAL	7,145	308,083

* does not include expired easements

Figure 26. Conservation Easements in Minnesota (BWSR 2021).

6.3 Summary of local plans

Minnesota has a long history of water management by local government, which included developing water management plans along county boundaries since the 1980s. The BWSR-led One Watershed, One Plan (1W1P) program is rooted in work initiated by the Local Government Water Roundtable (Association of Minnesota Counties, Minnesota Association of WDs, and Minnesota Association of SWCDs). The Roundtable recommended that local governments organize to develop focused implementation plans based on watershed boundaries. That recommendation was followed by the legislation (Minn. Stat. § 103B.801) that established the 1W1P program, which provides policy, guidance, and support for developing comprehensive watershed management plans:

- Align local water planning purposes and procedures on watershed boundaries to create a systematic, watershed-wide, science-based approach to watershed management.
- Acknowledge and build off existing local government structure, water plan services, and local capacity.
- Incorporate and make use of data and information, including WRAPS.
- Solicit input and engage experts from agencies, citizens, and stakeholder groups; focus on implementation of prioritized and targeted actions capable of achieving measurable progress.
- Serve as a substitute for a comprehensive plan, local water management plan (LWMP), or watershed management plan developed or amended, approved, and adopted.

The OTRW 1W1P has been approved for funding in the 2021 funding cycle and will begin the planning process over the course of 2021. Until the completion of a comprehensive watershed management plan in the OTRW, county and local WD water plans remain in effect per the Comprehensive Local Water Management Act (Minn. Stat. § 103B.301). Those plans may be updated with new information, or their expiration dates may be extended pending future participation in the 1W1P program. Local water plans and comprehensive watershed management plans incorporate implementation strategies aligned with or called for in TMDLs and WRAPS and are implemented by SWCDs, WDs, counties, state and federal agencies, and other partners. Furthermore, the local water plans and comprehensive watershed management plans share the goal of removing waterbodies from and preventing other waterbodies from being added to Minnesota's 303(d) Impaired Waters List. The commitment and support from the local governmental units will help ensure that the WRAPS and TMDL goals are carried successfully through implementation.

6.4 Examples of pollution reductions

Reliable means of reducing NPS pollutant loads are fully addressed in the OTRW WRAPS Report (MPCA 2020a), a document that is written to be a companion to this TMDL report. In order for the impaired waters to meet water quality standards, the majority of pollutant reductions in the OTRW will need to come from NPS. Agricultural drainage and surface runoff are major contributors of nutrients, *E. coli*, sediment, and increased flows throughout the watershed. As described in the OTRW WRAPS report, various agricultural BMPs have been demonstrated to be effective in reducing transport of pollutants to surface water. The combinations of BMPs discussed throughout the WRAPS process were derived from

Minnesota's NRS (MPCA 2015a) and related tools. As such, they were vetted by a statewide engagement process prior to being applied in the OTRW.

Selection of sites for BMPs will be led by LGUs, county SWCDs, WDs, and county planning and zoning, with support from state and federal agencies. These BMPs are supported by programs administered by the SWCDs and the NRCS. Local resource managers are well-trained in promoting, placing, and installing these BMPs. Some counties within the OTRW have shown significant levels of adoption of these practices. State and local agencies will need to work with landowners to identify priority areas for BMPs and practices that will help reduce nutrient runoff as well as streambank and overland erosion. Agencies, organizations, LGUs, and citizens alike need to recognize that resigning waters to an impaired condition is not acceptable. Throughout the course of the WRAPS and TMDL meetings, local partners endorsed the BMPs selected in the WRAPS report. These BMPs reduce pollutant loads from runoff (e.g., P, sediment, and pathogens) and loads delivered through drainage tiles or groundwater flow.

To help achieve NPS reductions, a large emphasis has been placed on public participation, where the citizens and communities that hold the power to improve water quality conditions are involved in discussions and decision-making. The watershed's citizens and communities will need to voluntarily adopt the practices at the necessary scale and rate to achieve the 10-year targets presented in the OTRW WRAPS Report. The WRAPS report also presents the pollutant goals and targets to the primary sources and the estimated years to meet the goals developed by the WRAPS Local Work Group. The strategies identified and relative adoption rates developed by the WRAPS Local Work Group were used to calculate the adoption rates needed to meet the pollutant 10-year targets. In addition to public participation, several government programs are in place to support a political and social infrastructure that aims to increase the adoption of strategies that will improve watershed conditions and reduce loading from NPS.

Many SWCDs, WDs, lake associations, and other organizations within the OTRW are active in these programs, and some provide technical and financial assistance on topics such as nutrient management, drainage, and other agricultural BMPs, septic system improvements, lakeshore restorations, urban stormwater runoff management, and more. The work of these organizations is significant in the OTRW for implementing BMPs and achieving NPS reductions. Additional government programs are those established for reducing permitted and nonpermitted sources further discussed in **Sections 6.1 and 6.2.**

Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites (MPCA 2014) notes that sites across Minnesota, including at the Otter Tail River, show reductions over the period of record for TSS, TP, ammonia, and biochemical oxygen demand. This report suggests that, while further reductions are still needed, municipal and industrial P loads and loads of runoff-driven pollutants (i.e. TSS and TP) are decreasing; a conclusion that lends assurance that the OTRW WRAPS and TMDL goals and strategies are reasonable and that long-term, enduring efforts to decrease erosion and nutrient loading to surface waters have the potential to reduce pollutant loads.

6.5 Funding

On November 4, 2008, Minnesota voters approved the Clean Water, Land and Legacy Amendment to the constitution to:

- protect drinking water sources;

- protect, enhance, and restore wetlands, prairies, forests, and fish, game, and wildlife habitat;
- preserve arts and cultural heritage;
- support parks and trails; and
- protect, enhance, and restore lakes, rivers, streams, and groundwater.

This is a secure funding mechanism for 25 years that generates over $100 million per year for the state's Clean Water Fund, with the explicit purpose of supporting water quality improvement projects.

Funding sources to implement TMDLs and water quality projects can come from local, state, federal, and/or private sources. Local or private examples may include tax revenue and cost share assistance from local WDs and lake improvement districts, or fundraising and donations from other organizations or interest groups. State examples from the Clean Water Fund may include BWSR's Watershed-based Implementation Funding or Clean Water Fund Competitive Grants (e.g., Projects and Practices). Federal examples may include conservation funds from NRCS, such as the Environmental Quality Incentives Program and Conservation Stewardship Program.

Watershed-based implementation funding is a noncompetitive process to fund water quality improvement and protection projects for lakes, rivers/streams, and groundwater. This funding allows collaborating local governments to pursue timely solutions based on a watershed's highest priority needs. The approach depends on the completion of a comprehensive watershed management plan developed under the 1W1P program or the Metropolitan Surface Water framework to provide assurance that actions are prioritized, targeted, and measurable.

BWSR has begun the transition of moving more of its available funding away from competitive grants and toward watershed-based implementation funding to accelerate water management outcomes, enhance accountability, and improve consistency and efficiency across the state. This approach allows more clean water projects to be implemented and helps local governments spend limited resources where they are most needed.

Watershed-based implementation funding assurance measures are based on fiscal integrity and accountability for achieving measurable progress towards water quality elements of comprehensive watershed management plans. Assurance measures will be used as a means to help grantees meaningfully assess, track, and describe use of these grant funds to achieve clean water goals through prioritized, targeted, and measurable implementation. The following assurance measures are supplemental to existing reporting and on-going grant monitoring efforts:

- understand contributions of prioritized, targeted, and measurable work in achieving clean water goals;
- review progress of programs, projects, and practices implemented in identified priority areas;
- complete Clean Water Fund grant work on schedule and on budget;
- leverage funds beyond the state grant.

From 2004 through 2019, approximately $93,740,000 has been spent addressing water quality issues in the OTRW through state and federally funded programs (MPCA 2020g, **Figure 27**). This total does not include all local government or private spending for stormwater and other clean water projects. CRP payments made up 47% of the amount equaling about $44,258,000. Approximately $12,000,000 of state funding via the Minnesota Public Facilities Authority was provided in 2018 for the construction of the new Detroit Lakes WWTP.

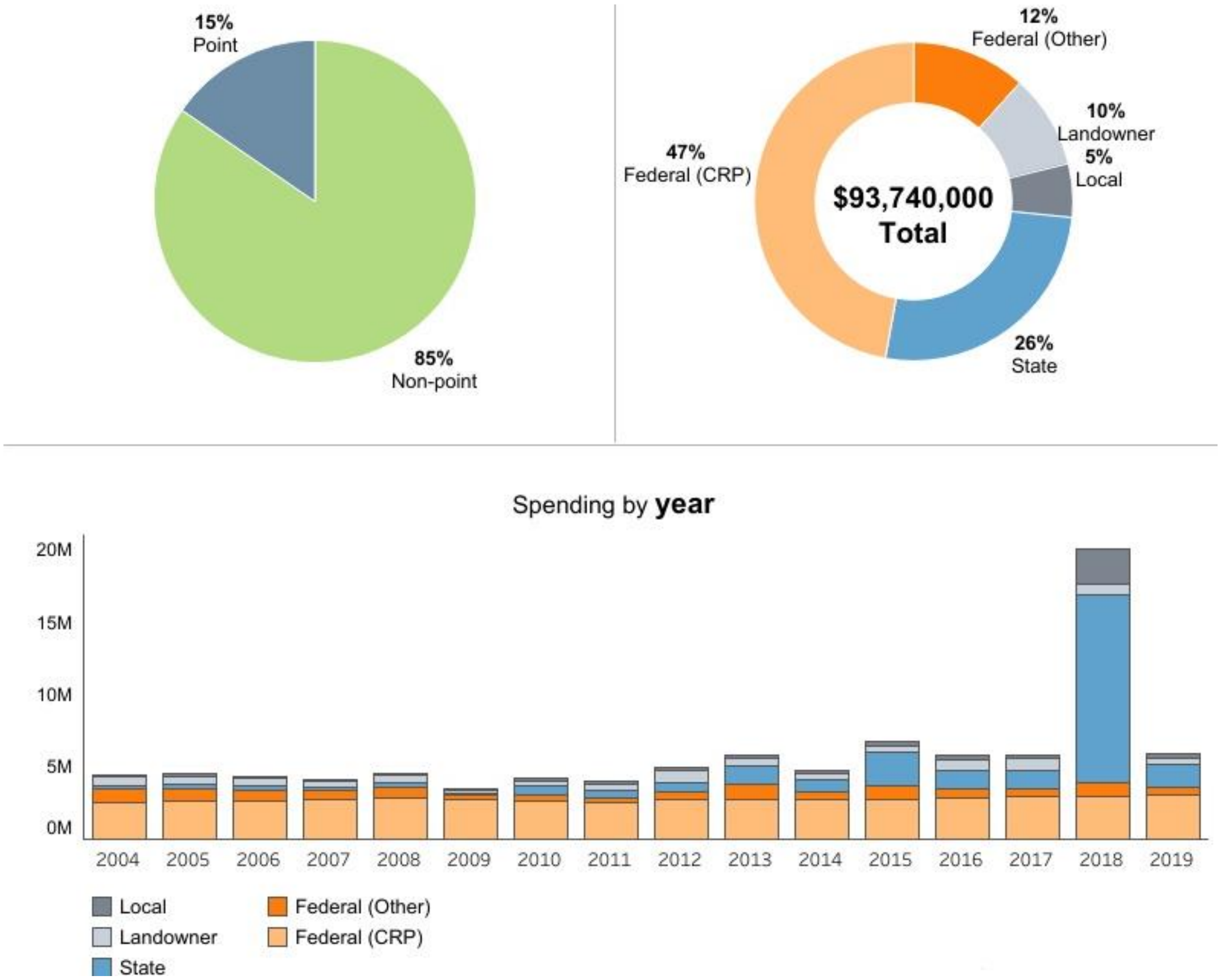


Figure 27. Spending addressing water quality issues in the OTRW (MPCA 2020g).

6.6 Reasonable Assurance Summary

In summary, significant time and resources have been devoted to identifying the most appropriate BMPs, providing means of focusing them in the OTRW, and supporting their implementation via state initiatives and dedicated funding. The OTRW WRAPS and TMDL process engaged partners to arrive at reasonable examples of BMP combinations that attain pollutant reduction goals. Minnesota is a leader in watershed planning as well as monitoring and tracking progress toward water quality goals and pollutant load reductions. Finally, examples cited herein confirm that BMPs and restoration projects have proven to be effective over time and, as stated by the State of Minnesota Court of Appeals in A15-1622 MCEA vs MPCA and MCES:

> *We conclude that substantial evidence exists to conclude that voluntary reductions from nonpoint sources have occurred in the past and can be reasonably expected to occur in the future. The Nutrient Reduction Strategy (NRS) provides substantial evidence of existing state programs designed to achieve reductions in nonpoint source pollution as evidence that reductions in nonpoint pollution have been achieved and can reasonably be expected to continue to occur.*

7. Monitoring

The foundation of effective water quality monitoring is the collection and analysis of water and biological samples. The OTRW TMDL and WRAPS project focuses on the 10-year assessment period (2008 through 2017). During the final two years of the assessment period (2016 to 2017), an intensive watershed monitoring program, described below, was performed to fill in several data gaps. In spite of this effort, more data is still needed to initially assess impairment within a majority of streams and lakes in the watershed.

Stream monitoring within the OTRW will continue primarily through the efforts of the MPCA, and a variety of other public and private organizations. The East Otter Tail SWCD, West Otter Tail SWCD, Becker SWCD, Otter Tail COLA, Becker COLA, PRWD, Buffalo-Red River Watershed District (BRRWD), and other lake associations have collectively established current and future monitoring goals for water quality throughout the watershed. This effort is aimed at collecting current measurements of water quality parameters and building a more robust data set for analyzing long-term trends in water quality within the watershed. The MPCA also has ongoing monitoring in the watershed.

Data from three water quality monitoring programs enables water quality condition assessment and creates a long-term data set to track progress towards water quality goals. BMPs implemented by LGUs will be tracked through BWSR’s e-Link system. These programs will continue to collect and analyze data in the OTRW as part of Minnesota’s Water Quality Monitoring Strategy (MPCA 2011). Data needs are considered by each program and additional monitoring is implemented when deemed necessary and feasible. These monitoring programs are summarized below:

Intensive Watershed Monitoring (MPCA 2020j) data provide a periodic but intensive “snapshot” of water quality throughout the watershed. This program collects water quality and biological data at stream and lake monitoring stations across the watershed for 1 to 2 years, every 10 years. To measure pollutants across the watershed the MPCA will re-visit and re-assess the watershed, as well as have some capacity to visit new sites in areas with BMP implementation activity.

Watershed Pollutant Load Monitoring Network (MPCA 2020k) data provide a continuous and long-term record of water quality conditions at the major watershed and subwatershed scale. This program collects pollutant samples and flow data to calculate continuous daily flow and sediment and nutrient loads. In the OTRW, there is an annual site in the Otter Tail River at Breckenridge and two seasonal (spring through fall) subwatershed sites, one in the Pelican River near Fergus Falls and one in the Otter Tail River near Elizabeth.

Citizen Stream and Lake Monitoring Program (MPCA 2020l) data provide a continuous record of waterbody transparency throughout much of the watershed. This program relies on a network of private citizen volunteers who make monthly lake and river measurements throughout the year. Approximately 105 citizens monitoring locations exist in the OTRW. This program, much like the efforts of the Otter Tail COLA, Becker COLA, and RMB Environmental Laboratories, relies on a network of private citizen volunteers who make regular lake and river measurements annually.

8. Implementation strategy summary

The strategies described in this section are potential actions to reduce *E. coli*, TSS, and P in the OTRW. A more detailed discussion on implementation strategies can be found in the OTRW WRAPS Report (MPCA 2020a).

8.1 Permitted sources

8.1.1 Construction stormwater

The WLA for stormwater discharges from sites where there is construction activity reflects the number of construction sites greater than one acre expected to be active in the watershed at any one time, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in Minnesota's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs, and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Section 23 of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. Construction activity must also meet all local government construction stormwater requirements.

8.1.2 Industrial stormwater

The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES/SDS Industrial Stormwater Permit coverage is required, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. Minnesota's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) and NPDES/SDS Nonmetallic Mining/Associated Activities General Permit (MNG490000) establish benchmark concentrations for pollutants in industrial stormwater discharges. If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS Permit and properly selects, installs, and maintains all BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. Industrial activity must also meet all local government construction stormwater requirements.

8.1.3 Municipal Separate Storm Sewer Systems

The MS4 General NPDES/SDS Permit requirements must be consistent with the assumptions and requirements of an approved TMDL and associated WLAs. The BMP stormwater control measure requirements are defined in the state's MS4 General NPDES/SDS Permit (MNR040000). The baseline years for each impaired stream or lake are provided in the TMDL tables. Any wasteload-reducing BMP implemented since the baseline year will be eligible to "count" toward an MS4's load reductions. If a BMP was implemented during or just prior to the baseline year, the MPCA is open to presentation of evidence by the MS4 Permit holder to demonstrate that it should be considered as a credit. The WRAPS report for these watersheds was developed with input from the stakeholders to determine the appropriate BMPs and implementation strategies to meet the MS4 goals for all the TMDLs presented in this TMDL report.

8.1.4 Wastewater

The MPCA issues permits for municipal (or domestic) and industrial WWTPs that discharge into waters of the state. The permits have site specific limits that are based on water quality standards. For WWTPs discharging into impaired reaches located within the OTRW, existing permit limits currently meet WLAs assigned in this TMDL report. Permits regulate discharges with the goals of protecting public health and aquatic life and assuring that every facility treats wastewater. In addition, SDS permits set limits and establish controls for land application of sewage.

8.1.5 Animal Feedlots

The MPCA issues NPDES permits or SDS permits for all CAFOs and non-CAFOs that have 1,000 or more AUs or for all federally defined CAFOs which have had a discharge, some of which are under 1,000 AUs in size. The NPDES and SDS permits include design, construction, operation, and maintenance standards that all CAFOs must follow. While no WLAs are calculated for CAFOs in this TMDL report, if the CAFOs are properly permitted and operated under the applicable NPDES or SDS permit, then the CAFOs are expected to be consistent with this TMDL.

As discussed in **Section 6.2.2,** many of the feedlots in the OTRW have never been inspected by the MPCA. However, the MPCA Feedlot Program has been able to make significant efforts in feedlot facility inspections and in other program implementation within the OTRW in 2017, 2018, and 2019. Nonetheless, these efforts are likely not sustainable due to current resource and staffing limitations, as well as other regional program requirements and priorities outside of the OTRW. Therefore, accepting feedlot program delegation, further described in **Section 6.2.2**, in Becker and Otter Tail Counties could continue bringing resources to the OTRW to help address NPS of *E. coli*, sediments, and nutrients. These resources would be in the form of additional feedlot facility inspections, feedlot registration and permitting, education and outreach, and technical assistance, and having these resources at the county level could improve the likelihood that NPS of pollution from animal feedlots and manure application is addressed in a more timely and consistent manner within the OTRW.

If feedlot program delegation is not explored, there are still a number of other federal, state, and local agencies and organizations that are active within the OTRW and that are available to assist farmers and feedlot owners. Examples may include the United States Department of Agriculture’s NRCS and Farm Service Agency, the Minnesota Department of Agriculture, the University of Minnesota Extension, agriculture and livestock producer groups, SWCDs, WDs, lake associations, and more. These agencies and organizations may be available to help OTRW feedlot owners and agricultural producers with education and outreach to help producers understand applicable rules, requirements, and BMPs, as well as with technical and financial assistance for facility and equipment upgrades. While these resources are more voluntary in nature instead of regulatory, these efforts could still help address NPS of pollution from animal feedlots and manure application within the OTRW through increased BMP implementation, with improved efficiency of equipment and facilities, and by eliminating potential sources of runoff from feedlots, crop fields, and manure storage areas.

8.2 Nonpermitted sources

A summary of potential BMPs to reduce NPS pollutants is provided in **Table 46**. Potential BMPs and implementation strategies are explored more thoroughly in the OTRW WRAPS Report (MPCA 2020a), and are expected to be brought forward into the OTRW 1W1P planning process as well.

As previously discussed, reduction of NPS pollutants will need to be the focus of implementation efforts in the OTRW, and efforts should focus on the major anthropogenic sources identified in the source assessment. This is also true for lakes, as NPS pollutants from lakeshed runoff should likely be addressed before internal loading. If in-lake restoration techniques for internal nutrient removal are necessary, such as chemical treatments, they should be preceded by or occur alongside long term and significant efforts to reduce NPS of nutrients, sediment, and other pollutants. As discussed in **Section 6.2,** several programs and other resources exist to support implementation of NPS reduction BMPs in the OTRW. A large emphasis will need to be placed on public participation or buy-in, with communities and organizations within the OTRW voluntarily adopting the practices and programs at the necessary scale and rate to achieve the reduction goals.

Table 46. Summary of potential BMPs by land type and their primary targeted pollutants (MPCA 2020a).

Land use	Restoration and Protection Strategies	By pollutant or Stressor						
	Common management practices by land use	Sediment	Hydrology	Nitrogen	Phosphorus	*E. coli*	Habitat	Dissolved Oxygen
Cultivated Crops	Improved fertilizer management	-	-	X	X	-		X
	Grassed waterway	X	-	X	-	-		-
	Conservation tillage	X	-	-	X			-
	Crop rotation (including small grain)			X	-			-
	Critical area planting	X			-		-	-
	Improved manure field application	-	-	X	-	-		X
	Cover crops	X	-	-	X	-		-
	WASCOBS, terraces, flow-through basins	X	X	-	X	-		-
	Buffers, border filter strips		-	X	-	X	X	X
	Contour strip cropping (50% crop in grass)	X	X	X	X	X	-	-
	Wind Breaks	-			-			-
	Conservation cover (replacing marginal farmed areas)	X	X	X	X	X	-	-
	In/near ditch retention/treatment	-	-	-	-	-		-
	Alternative tile intakes	X			X	-		-
	Treatment wetland (for tile drainage system)		-	X	-			
	Controlled drainage, drainage design		X	X	-			-
	Saturated buffers		-	X	-			-
	Wood chip bioreactor			X	-			-
	Wetland Restoration	X	X	X	X	X	X	-
	Retention Ponds	X	X	X	X	X	-	-
	Mitigate agricultural drainage projects	X	X	X	X	X	-	-
	Maintenance and new enrollment of BMPs, CRP, RIM, etc.	X	X	X	X	X	-	-

Land use	Restoration and Protection Strategies	By pollutant or Stressor						
	Common management practices by land use	Sediment	Hydrology	Nitrogen	Phosphorus	*E. coli*	Habitat	Dissolved Oxygen
Pastures	Rotational grazing/improved pasture vegetation management	X			X	X	X	-
	Livestock stream exclusion and watering facilities	X			X	X	X	-
Cities & yards	Nutrient/fertilizer and lawn mgt.	-	-	-	-	-		-
	Infiltration/retention ponds, wetlands	-	-	X	-			-
	Rain gardens, rain barrels		-					
	Street sweeping & storm sewer mgt.	-						
	Trees/native plants	-			-			-
	Snow pile management		-					
	Permeable pavement for new construction	-	-					
	Construction site erosion control	X	X	-	X		-	-
SSTS	Maintenance and replacement/upgrades			X	X	X		-
Feedlots	Feedlot runoff controls including buffer strips, clean water diversions, etc. on feedlots with runoff			X	X	X		-
Streams, ditches, & ravines	Protect and restore buffers, natural features	X	X	X			X	
	Reduce or eliminate ditch clean-outs	X		X			X	
	Bridge/culvert design	X	X				X	
	Streambank stabilization	X		X	X		-	-
	Ravine/stream (grade) stabilization	X		X	X			-
	Stream channel restoration and floodplain reconnection	X		X	X		X	-
Lakes & Wetlands	Near-water vegetation protection and restoration	X		X	X		X	-
	In-water management and species control			X	-		X	-
	Reduction of in-water loading or internal release of phosphorus within lakes, including rough fish management, alum or iron treatment, lake drawdown, hypolimnetic withdrawal, etc.				X		-	-
Grassland & Forest	Protect and restore areas in these land uses, increase native species populations	X	-	X	X		X	-

"X" - strong benefit to water quality improvement as related to the specified parameter, "-" - moderate benefit to water quality as related to the specified parameter, blank - little benefit to water quality as related to the specified parameter.

8.3 Cost

The CWLA requires that a TMDL report include an overall approximation of the cost to implement a TMDL [Minn. Stat. 2007 § 114D.25]. The costs to implement the activities outlined in the OTRW WRAPS (MPCA 2020a) are approximately $20 to $40 million over the next 20 years. For this TMDL report, an approximate cost estimate ranges from $5 million to $15 million. This range reflects the level of uncertainty in the source assessment and addresses the high priority sources identified in **Section 3.6**. The cost includes increasing local capacity to oversee implementation in the watershed and the voluntary actions needed to achieve reductions. Required buffer installation and replacement of ITPHS systems are not included.

8.4 Adaptive management

Adaptive management is an iterative implementation process that makes progress toward achieving water quality goals while using new data and information to reduce uncertainty and adjust implementation activities. The State of Minnesota has a unique opportunity to adaptively manage water resource plans and implementation activities. This opportunity resulted from a voter-approved tax increase to improve state waters. The resulting interagency coordination effort is referred to as the Minnesota Water Quality Framework, which works to monitor and assess Minnesota's major watersheds every 10 years (BWSR 2014). This framework supports ongoing implementation and adaptive management of conservation activities and watershed-based local planning efforts utilizing regulatory and nonregulatory means to achieve water quality standards.

Implementation of TMDL related activities can take many years, and water quality benefits associated with these activities can also take many years. As the pollutant source dynamics within the watershed are better understood, implementation strategies and activities will be adjusted and refined to efficiently meet the TMDL and lay the groundwork for de-listing the impaired reaches and lakes. The follow-up water monitoring program outlined in **Section 7** will be integral to the adaptive management approach, providing assurance that implementation measures are succeeding in achieving water quality standards. Adaptive management does not include changes to water quality standards or LC. Any changes to water quality standards or LC must be preceded by appropriate administrative processes, including public notice and an opportunity for public review and comment.

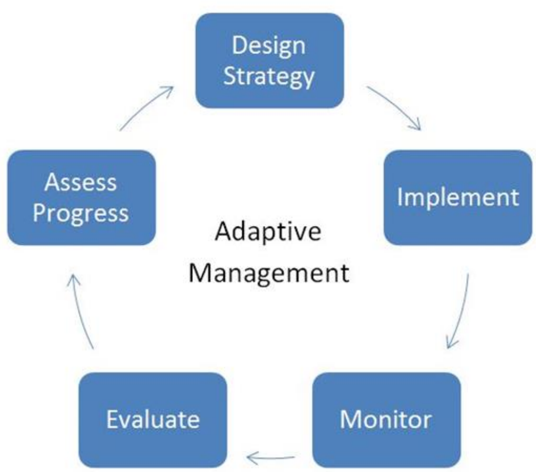


Figure 28. Adaptive management

A list of implementation strategies in the WRAPS report prepared in conjunction with this TMDL report will focus on adaptive management (**Figure 28**). Continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategy for achieving the water quality goals established in this TMDL report. Management activities will be changed or refined to efficiently meet the TMDLs and lay the groundwork for de-listing the impaired waterbodies.

9. Public Participation

Public participation was a major focus during the OTRW's WRAPS and TMDL Project. In a watershed with differing private, public, and tribal land ownership, the public participation process must incorporate both technical stakeholder engagement and citizen engagement. The WRAPS process seeks to engage residents within the OTRW by connecting cities, counties, businesses and other stakeholders to ensure that their ideas, concerns, and visions for future conditions are understood and incorporated into planning activities throughout the WRAPS creation process.

There are many stakeholder groups within the OTRW that work with SWCD and WD personnel and are already involved in restoration and outreach efforts throughout the watershed. Stakeholder organizations include Otter Tail Coalition of Lakes Associations (COLA), Becker COLA, The Nature Conservancy, Ducks Unlimited, Pheasants Forever, Trout Unlimited, Fargo-Moorhead Walleyes, Minnesota Deer Hunters Association, National Wild Turkey Federation, Central Minnesota Irrigators (CMIC), Central Lakes College Agriculture and Energy Center (CLC), Minnesota Waters, Freshwater Society, local co-ops, Red River Basin Commission, International Waters Institute, and many more wildlife, conservation, sportsman, and local civic organizations. SWCDs, WDs and other management organizations in the OTRW make great efforts to continue working closely with these groups in an effort to develop projects that are mutually beneficial.

During the WRAPS process, watershed partners held periodic update meetings to share local knowledge about problems and to guide the development of potential implementation strategies based on technical data. These discussions helped ensure that the TMDL and WRAPS reports will be useful in coordinating future projects in the watershed. The following meetings and requests for review were held during the development of the TMDL and WRAPS reports:

- 9/6/2019 – Watershed Partners meeting to discuss the MPCA SID report, updates about the Minnesota Department of Natural Resources (DNR) Geomorphology study, and the draft TMDL and WRAPS reports.
- 1/9/2020 – Watershed Partners meeting between East Otter Tail SWCD, Houston Engineering, Inc., and PRWD to review and discuss PRWD staff's input for the preliminary draft TMDL and WRAPS reports.
- 1/24/2020 – Watershed Partners meeting to review the TMDL and WRAPS results and discuss moving into the 1W1P process next.
- 3/17/2020 – Request for review and comments on the preliminary draft TMDL and WRAPS reports sent to Watershed Partners by email.
- 5/8/2020 – Request for review and comments on the revised draft WRAPS report sent to Watershed Partners by email.
- 5/18/2020 – Offer for virtual presentations to update stakeholders on the development of the TMDL and WRAPS report sent to Watershed Partners by email.
- 8/13/2020 – Informational video and survey prepared by East Otter Tail SWCD staff shared by email with Watershed Partners and stakeholders to solicit participation and input on continued development of the TMDL and WRAPS reports.

- 9/9/2020 – Request for review and comments on the revised draft TMDL report sent to Watershed Partners by email.
- 12/18/2020 - Request for review and comments on the revised draft TMDL and WRAPS reports sent to Watershed Partners by email.
- 12/29/2020- Review and Q&A Session hosted virtually with Watershed Partners on the revised draft TMDL and WRAPS.

In addition, local staff attended other local stakeholder meetings to update them on the WRAPS process, including Becker COLA and Otter Tail COLA. Local and state staff and other watershed partners also teamed up with the University of Minnesota Water Resources Center to host "Aqua Chautauqua" events in the summers of 2017, 2018, and 2019, in both Fergus Falls and Detroit Lakes. These interactive and educational events were hosted as part of the WRAPS and TMDL development process but were focused more so on water quality issues and education in general.

The following public participation events were held as a part of this process:

- 11/14/2017- Education and Outreach Planning Meeting.
- 12/13/2017- Education and Outreach Planning Meeting 2.
- 1/29/2018 – Education and Outreach Planning Meeting 3.
- 3/12/2018- Education and Outreach Planning Meeting 4.
- 3/28/2018- Education and Outreach Planning Meeting 5.
- 6/8/2018- 6/9/2018- Hosted Summer Fest Booth in Fergus Falls.
- 6/16/2018- Hosted Turtle Fest Booth in Perham.
- 6/21/2018- Attended Otter Tail COLA meeting.
- 6/19/2018- 6/21/2018- Hosted East Otter Tail County Fair Booth in Perham.
- 7/19/2018- 7/22/2018- Hosted West Otter Tail County Fair Booth in Fergus Falls.
- 7/26/2018- 7/28/2018- Hosted Becker County Fair Booth in Detroit Lakes.
- 8/16/2018- Attended Becker COLA meeting.
- 9/9/2018- Headwaters Day Fair Booth in Breckenridge.
- 3/22/2021 – Informational presentation given virtually to the BRRWD supervisors about the status and content of the TMDL and WRAPS reports.
- 3/23/2021 – Informational presentation given virtually to the Otter Tail County Commissioners about the status and content of the TMDL and WRAPS reports.
- 3/31/2021 – Informational presentation given virtually to the Fergus Falls City Council about the status and content of the TMDL and WRAPS reports.
- 4/5/2021 – Informational presentation given virtually to the Cormorant Lakes WD supervisors about the status and content of the TMDL and WRAPS reports.

- 4/21/2021 – Informational presentation given virtually to the East Otter Tail SWCD supervisors about the status and content of the TMDL and WRAPS reports.
- 4/22/2021 – Informational presentation given virtually to the PRWD supervisors about the status and content of the TMDL and WRAPS reports.

Additional public participation efforts were planned and scheduled for the summer of 2020, but due to the COVID-19 pandemic, most organizations and activities were closed and not meeting or were cancelled. Public participation efforts that occurred shifted to online formats, such as the informational videos and virtual presentations and meetings listed above. It is expected that in-person meetings and presentations will resume during the summer of 2021 as conditions allow. Therefore, public participation efforts, whether in-person or virtually, will continue concurrently with efforts to finalize the OTRW TMDL and WRAPS reports by June 2021, including additional efforts with the Becker and Otter Tail COLAs, agricultural groups, and other locally elected officials. Offers to present the status and content of the TMDL and WRAPS reports have been extended to each of these groups. Public participation efforts will also continue in the OTRW for future planning efforts, including local water planning and 1W1P efforts.

9.1 Accomplishments and future plans

These watershed partners recognize the importance of informing citizens of current watershed activities and educating the citizens in the benefits of conservation, preservation and enhancement of natural resources. SWCD and WD staff and boards realize that optimum water management practices result when people affected by a water resources issue are sufficiently educated. For this reason, they have taken an active position in publicizing its activities and providing outreach to the public. Garnering support and gathering information from the public is often accomplished through a series of mailers, workshops, discussions, and meetings. The SWCDs have sponsored outreach events such as Breakfast at the Farm, lake shoreline tours, soil health demonstration plots, and irrigator workshops. The WDs have sponsored outreach events such as community education, school education workshops and programs, service club and Lake Association education and presentations, regional salt applicator workshops, contractor training, and Aquatic Invasive Species state and regional conferences.

The SWCDs, WDs, COLAs, MPCA, and other agencies and organizations also have the goal of involving citizens in water quality monitoring across the watershed and will often recruit volunteers to collect important water samples and/or measurements. Local residents have the opportunity to be a part of many sampling/data collection programs such as Lake Level Minnesota, a monitoring program set up through the DNR, the Citizens Lake or Stream Monitoring Program (CLMP/CSMP) through the MPCA, and lake monitoring through the Becker and Otter Tail COLAs.

The existing LWMPs have extensive lists of protection and restoration activities planned through the next decade. General activities include (but are not limited to) stormwater management projects, soil health management, aquatic invasive species prevention and management, reduction of altered hydrologic conditions, and groundwater quality and quantity protection. The SWCDs and WDs have also put in place extensive programs for monitoring progress toward goals as a result of implementation of practices.

Several of the many examples of past collaborative successes include multiple nutrient reduction projects led by the Becker County SWCD, precision irrigation and cover crop assistance led by East Otter Tail SWCD, urban stormwater nutrient reduction and wetland restoration efforts by PRWD, curly-leaf pondweed management by Cormorant Lakes WD, and dam modification projects on Fish Lake, Lizzie Lake and Prairie Lake that reconnected 20 miles of the Pelican River led by the Pelican Group of Lakes Improvement District. These examples involved numerous projects, as well as many organizational and funding partners that were critical to their success.

Since water quality is among the priorities of the watershed partners' management activities, future public participation events will continue to be coordinated by watershed partners. WD staff will update, educate, and engage stakeholders on water quality issues through the typical communications, including watershed plan update events and website communication. A primary objective of this public participation is to create understanding of water quality problems and solutions that are available, and to build motivation to make changes with those who will be needed to voluntarily implement BMPs. As a trusted authority on water issues in the area, the watershed partners are uniquely suited to provide information and leadership on this topic.

Expectations are that future project implementation will continue to be guided by the existing LWMPs. However, projects and management will also be guided by the information gained from the WRAPS report and this TMDL report, during the 1W1P process (which is approved for funding and scheduled to begin in 2021), and/or through partnerships with local SWCDs, adjacent WDs, the Red River Watershed Management Board, and other organizations.

9.2 Public notice

An opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from May 10, 2021 through June 9, 2021. There were two comment letters received and responded to as a result of the public comment period. Portions of the draft TMDL report were revised in addressing and responding to the comment letter received from the City of Detroit Lakes on June 7, 2021. Boundary conditions were applied to two reaches impaired due to *E. coli,* which resulted in WLAs for domestic WWTPs and permitted MS4s upstream of the boundaries being removed from the associated TMDL allocations tables (**Table 21** and **Table 25**). The boundary conditions were applied, and the applicable TMDL allocations tables revised, to ensure that the potential point and nonpoint sources within the boundary condition areas that may contribute to the impairment are included in the appropriate allocations, and to ensure that the point and nonpoint sources outside of the boundary condition areas that do not likely contribute to the impairment are allocated in the upstream boundary condition load. After the conclusion of the public comment period and to account for the addition of these boundary conditions, the *E. coli* pollutant source summary for domestic and industrial wastewater and municipal stormwater in **Section 3.6.1.2** and the *E. coli* WLA methodology in **Section 4.2.3** of this TMDL report were revised, and **Section 4.2.4** was added. Revisions and responses to comments were then shared with the other cities with permitted WWTPs or MS4 permits included in the draft TMDL report. Additional discussion and review then ensued between the MPCA and City of Fergus Falls, resulting in minor revisions or clarifications to the TMDL report in consideration with the City of Fergus Falls' comments and concerns.

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Appendices

1. St. Clair Lake TMDL

Table 16. St. Clair Lake TMDL and Allocations

St. Clair Lake Load Component			Existing	Goal		Reduction	
			lb/yr	lb/yr	lb/day	lb/yr	%
Wasteload Allocations	**Total WLA**		**902**	**736**	**2.018**		
	Construction			8	0.022		
	Industrial			8	0.022		
	WWTP[1]		342*	437	1.197	95	28%
	Detroit Lakes MS4	*Direct drainage*	*21*	*12*	*0.033*	*-9*	*-42%*
		Ditch 1	*272*	*137*	*0.375*	*-135*	*-50%*
		Ditch 14	*267*	*134*	*0.368*	*-133*	*-50%*
		Subtotal	560	283	0.776	-277	-49%
Load Allocations	**Total LA**		**288**	**168**	**0.461**		
	Long Lake Outflow[2]		45	45	0.123	0	0%
	Internal Load		22	0	0.000	-22	-100%
	Groundwater		13	8	0.022	-5	-38%
	Atmosphere		30	30	0.082	0	0%
	Unregulated runoff	*Direct drainage*	*29*	*14*	*0.040*	*-15*	*-50%*
		Ditch 1	*147*	*70*	*0.191*	*-77*	*-52%*
		Ditch 14	*2*	*1*	*0.002*	*-1*	*-62%*
		Subtotal	178	85	0.233	-93	-52%
LOADING CAPACITY				**1,005**	**2.753**		
MOS				**-101**	**-0.275**		
TOTAL			**1,190**	**904**	**2.477**	**-286**	**-24%**

* The Existing Load for the Detroit Lakes WWTF is based on actual effluent loads from the 2003-2012 discharge monitoring records and does not reflect the NPDES permitted phosphorus effluent limit from that time period.

[1] The WWTP goal load is greater than the existing load to account for population growth projections (Reserve Capacity)

[2] Phosphorus loads from the upstream Long Lake drainage area are the load received by St. Clair Lake from the Long Lake *outlet* as the phosphorus loads have already undergone some removal processes through the treatment provided by Long Lake

2. Lower Otter Tail River Turbidity TMDL

Table 6. Load Allocation

Flow Zone	TMDL*	WLA for Stormwater*	MOS*	LA*
Low flow	56.1	1	17	38
Dry conditions	71.6	1	12	59
Mid-range flows	90.6	1	7	83
Moist conditions	114.1	2	15	97
High flow	144.6	2	14	129

* Units: tons/day

3. OTRW aquatic life and aquatic recreation use impairments not addressed in this TMDL report

WID	Waterbody Name	Designated Use Class[1]	Affected Use[2]	Listing Year	Proposed EPA Category[3]	Impairment/ Parameter	Pollutant or Stressors[4]	Reason(s) for not developing a TMDL in this Report
09020103 -526	Toad R, Little Toad Lk to T138 R38W S30, SW corner	1B, 2Ag, 3	AQL	2020	4C	Fish bioassessments	Multiple[5]	MPCA has evaluated this impairment for recategorizing to 4C on the 2022 Impaired Waters List as no conventional pollutants are strongly supported as primary stressors.
09020103 -532	Otter Tail R, Rice Lk to Mud Lk	1C, 2Bdg, 3	AQL	1998	5	Dissolved Oxygen		MPCA determined that a TMDL for this impairment should be deferred at this time as there was insufficient information for conventional pollutants.
09020103 -764	JD 2, Unnamed ditch along 190th St to Otter Tail R	2Bg, 3	AQL	2020	5	Dissolved Oxygen		MPCA determined that a TMDL for this impairment should be deferred at this time as there was insufficient information for conventional pollutants.
			AQL	2020	5	Fish bioassessments	Multiple[6]	Further evaluation is needed as nonconventional pollutants are strongly supported as stressors, while conventional pollutants like low DO and high TSS are only somewhat supported as stressors.
09020103 -767	Pelican R, Lk Lizzie to Reed Cr	2Bg, 3	AQL	2020	5	Dissolved Oxygen		Houston Engineering, Inc. determined that the low dissolved oxygen is loosely related to elevated phosphorus and water temperatures, as well as low flows, but insufficient data is available to complete the applicable models and TMDL at this time.
			AQL	2020	5	Fish bioassessments	Loss of connectivity, Insufficient habitat, Low dissolved oxygen[7]	Further evaluation is needed as loss of connectivity and insufficient habitat are nonpollutants, while low dissolved oxygen is somewhat supported as a stressor but additional evaluation of that impairment is needed as well.
09020103 -772	Pelican R, Highway 10 to Detroit Lk	2Bg, 3	AQL	2020	5	Dissolved Oxygen		MPCA has decided to defer these impairments due to a large scale restoration project that is being planned for upstream of this reach. These impairments may be expected to improve and possibly meet standards in the future as a result of the completed restoration project. More evaluation will be needed in the future.
			AQL	2020	5	Benthic macroinvertebrates bioassessments	Multiple[8]	
			AQL	2020	5	Fish bioassessments	Multiple[9]	

WID	Waterbody Name	Designated Use Class[1]	Affected Use[2]	Listing Year	Proposed EPA Category[3]	Impairment/ Parameter	Pollutant or Stressors[4]	Reason(s) for not developing a TMDL in this Report
03-0195-00	Height of Land Lake	2B, 3	AQR	2010	5	Nutrients / Eutrophication		MPCA has deferred this impairment as observed average phosphorus measures in this shallow lake narrowly exceeded applicable water quality standards. More evaluation may be needed in the future.
03-0206-00	Upper Egg	2B, 3	AQR	2020	Not Applicable	Nutrients / Eutrophication		This lake is wholly within the White Earth Nation tribal boundaries. MPCA is not authorized to complete a TMDL for this waterbody.
03-0213-00	Waboose	2B, 3	AQR	2020	Not Applicable	Nutrients / Eutrophication		This lake is wholly within the White Earth Nation tribal boundaries. MPCA is not authorized to complete a TMDL for this waterbody.
03-0235-00	Mallard	2B, 3	AQR	2020	Not Applicable	Nutrients / Eutrophication		This lake is wholly within the White Earth Nation tribal boundaries. MPCA is not authorized to complete a TMDL for this waterbody.
03-0265-00	Eagle	2B, 3	AQL	2020	4C or 5	Fish bioassessments	None	Lakes SID report lists no conventional pollutants as stressors. MPCA may evaluate this impairment for recategorizing to 4C on a future Impaired Waters List
03-0506-00	Little Cormorant	2B, 3	AQL	2020	5	Fish bioassessments	Eutrophication	Lakes SID report supports eutrophication as a stressor; more evaluation may be needed as this report was completed after the start of the WRAPS and TMDL development.
03-0588-00	Upper Cormorant	2B, 3	AQL	2020	5	Fish bioassessments	Eutrophication	Lakes SID report supports eutrophication as a stressor; more evaluation may be needed as this report was completed after the start of the WRAPS and TMDL development.
03-0602-00	Middle Cormorant	2B, 3	AQL	2020	4C or 5	Fish bioassessments	Physical habitat alteration	Lakes SID report supports physical habitat alteration, a nonpollutant, as a stressor. More evaluation may be needed. MPCA may evaluate this impairment for recategorizing to 4C on a future Impaired Waters List
56-0310-00	Walker	2B, 3	AQL	2020	5	Fish bioassessments	Eutrophication, Temp. regime changes, Decreased dissolved oxygen	Lakes SID report supports eutrophication, temperature regime changes, and decreased dissolved oxygen as a stressors; more evaluation may be needed as this report was completed after the start of the WRAPS and TMDL development.

WID	Waterbody Name	Designated Use Class[1]	Affected Use[2]	Listing Year	Proposed EPA Category[3]	Impairment/ Parameter	Pollutant or Stressors[4]	Reason(s) for not developing a TMDL in this Report
56-0328-00	Little McDonald	2B, 3	AQL	2020	4C or 5	Fish bioassessments	Physical habitat alteration	Lakes SID report supports physical habitat alteration, a nonpollutant, as a stressor. More evaluation may be needed. MPCA may evaluate this impairment for recategorizing to 4C on a future Impaired Waters List
56-0335-00	Paul	2B, 3	AQL	2020	4C or 5	Fish bioassessments	Physical habitat alteration	Lakes SID report supports physical habitat alteration, a nonpollutant, as a stressor. More evaluation may be needed. MPCA may evaluate this impairment for recategorizing to 4C on a future Impaired Waters List
56-0386-01	Big McDonald	2B, 3	AQL	2020	5	Fish bioassessments	Physical habitat alteration, Temperature regime changes, Decreased dissolved oxygen	Lakes SID report supports physical habitat alteration, a nonpollutant, as well as temperature regime changes and decreased dissolved oxygen as a stressors, however, more evaluation may be needed as this report was completed after the start of the WRAPS and TMDL development.
56-0448-00	Anna	2B, 3	AQL	2020	4C or 5	Fish bioassessments	None	Lakes SID report lists no conventional pollutants as stressors. MPCA may evaluate this impairment for recategorizing to 4C on a future Impaired Waters List
56-0519-00	West Silent	2B, 3	AQL	2020	4C or 5	Fish bioassessments	None	Lakes SID report lists no conventional pollutants as stressors. MPCA may evaluate this impairment for recategorizing to 4C on a future Impaired Waters List
56-0684-00	Fish	2B, 3	AQL	2020	5	Fish bioassessments	Eutrophication	Lakes SID report supports eutrophication as a stressor; more evaluation may be needed as this report was completed after the start of the WRAPS and TMDL development.
56-0867-00	Alice	2B, 3	AQR	2022 [10]	5	Nutrients / Eutrophication		Assessment of this lake occurred after the preparation for and development of this TMDL report. MPCA will address this impairment with a future TMDL.
56-0877-00	Jewett	2B, 3	AQL	2020	4C or 5	Fish bioassessments	Physical habitat alteration	Lakes SID report supports physical habitat alteration, a nonpollutant, as a stressor. More evaluation may be needed. MPCA may evaluate this impairment for recategorizing to 4C on a future Impaired Waters List

[1]Designated use classifications and applicable water quality standards are further described in **Section 2**.
[2]AQL = aquatic life use; AQR = aquatic recreation use.

[3]The Proposed EPA Category column indicates the proposed category after or upon approval of this TMDL report. All waters in the watershed that are currently classified as Category 5 on Minnesota's 2020 303(d) Impaired Waters List indicates an impaired status and a TMDL plan has not been completed. Those indicated as category 5 in the Proposed EPA Category column above will be reevaluated as part of the next applicable assessment period for the OTRW, with MPCA's Intensive Watershed Monitoring currently scheduled to begin in 2027 (MPCA 2020j). Recategorizations will not be final until they are approved by EPA as part of Minnesota's Impaired Waters List. Proposed categories are provided for those listings that have been further assessed and are proposed for recategorization as either 4A or 4C:

Category 4a: A water is placed in Category 4A when all TMDLs needed to result in attainment of all applicable water quality standards have been approved or established by EPA.

Category 4C: A water is placed in Category 4C when the state demonstrates that the failure to meet an applicable water quality standard is not caused by a pollutant, but instead is caused by other types of pollution. Waterbodies placed in Category 4C do not require the development of a TMDL.

[4]Stressors for aquatic life impairments in streams are further described in MPCA's Otter Tail River Watershed SID Report (MPCA 2019b), and stressors for aquatic life impairments in lakes are further described in DNR's and MPCA's Otter Tail River Watershed SID Report – Lakes (DNR and MPCA 2019)

[5]Insufficient physical habitat is convincingly supported and loss of longitudinal connectivity is strongly supported as primary stressors; high suspended sediment is somewhat supported as a stressor.

[6]Loss of longitudinal connectivity, flow regime instability, and insufficient physical habitat are strongly supported as primary stressors; high suspended sediment and low DO are somewhat supported as stressors.

[7]Loss of longitudinal connectivity is convincingly supported as a primary stressor; insufficient physical habitat and low DO are somewhat supported as stressors.

[8]Low DO is strongly supported as a primary stressor; flow regime instability, insufficient physical habitat, and high suspended sediment are somewhat supported as stressors.

[9]High suspended sediment, low DO, and flow regime instability are somewhat supported as primary stressors.

[10]Lake Alice is expected to be listed on Minnesota's 2022 303(d) Impaired Waters List.

4. Individual Subwatershed Maps

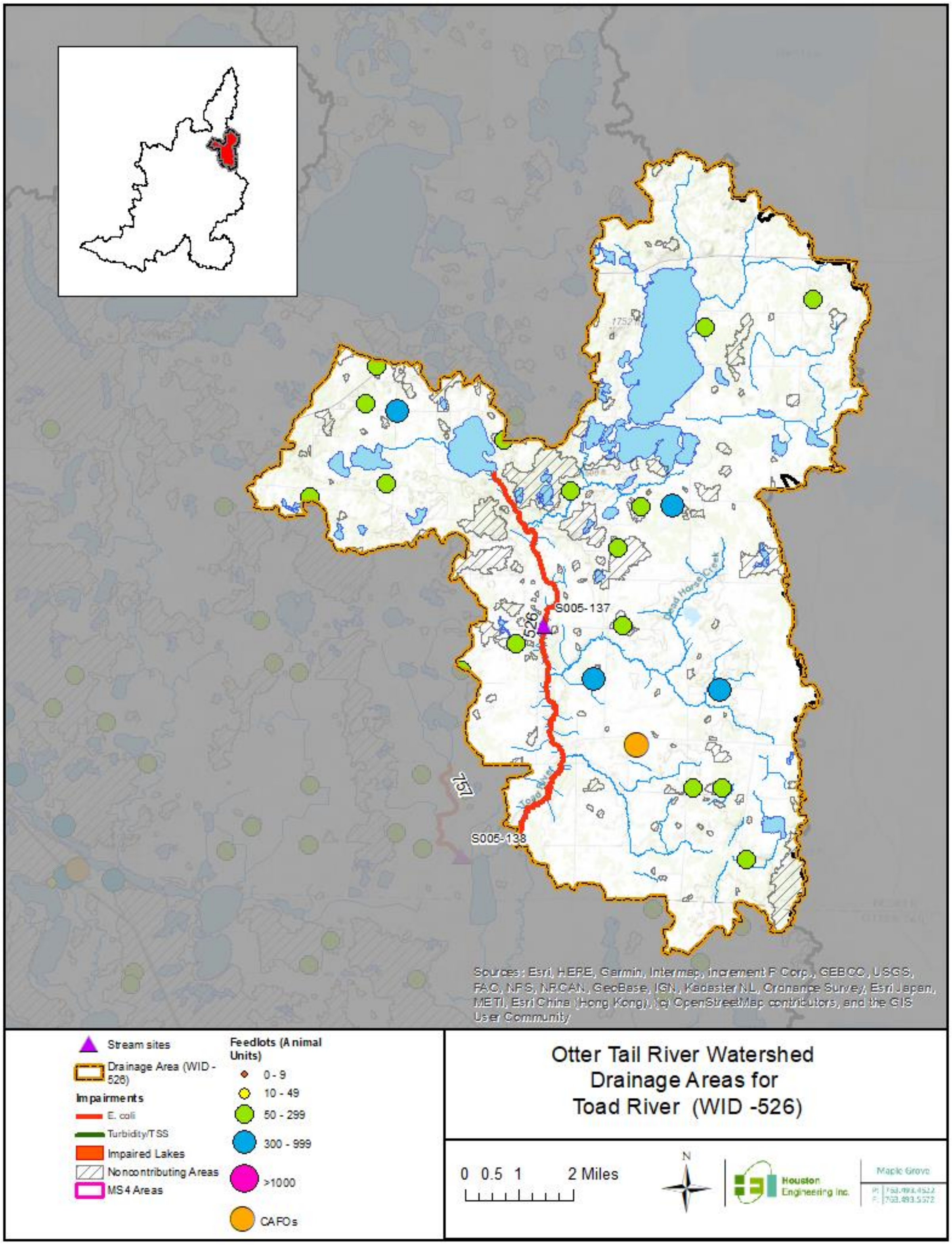

Figure 1. Drainage area of Toad River, Little Toad Lake to T138 R38W S30, SW corner (WID 09020103-526).

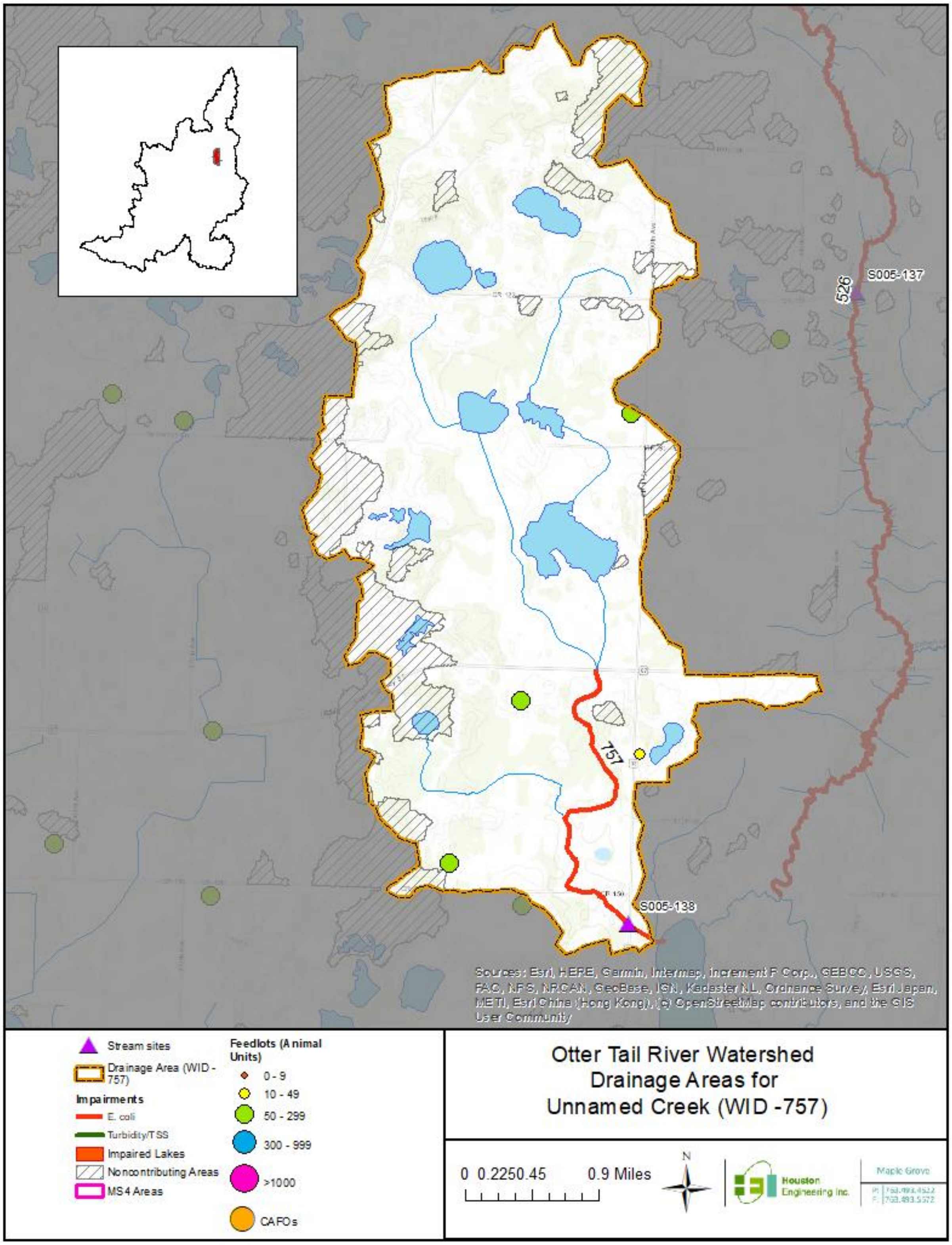

Figure 2. Drainage area of Unnamed Creek, Unnamed Creek to Dead Lake (WID 09020103-757).

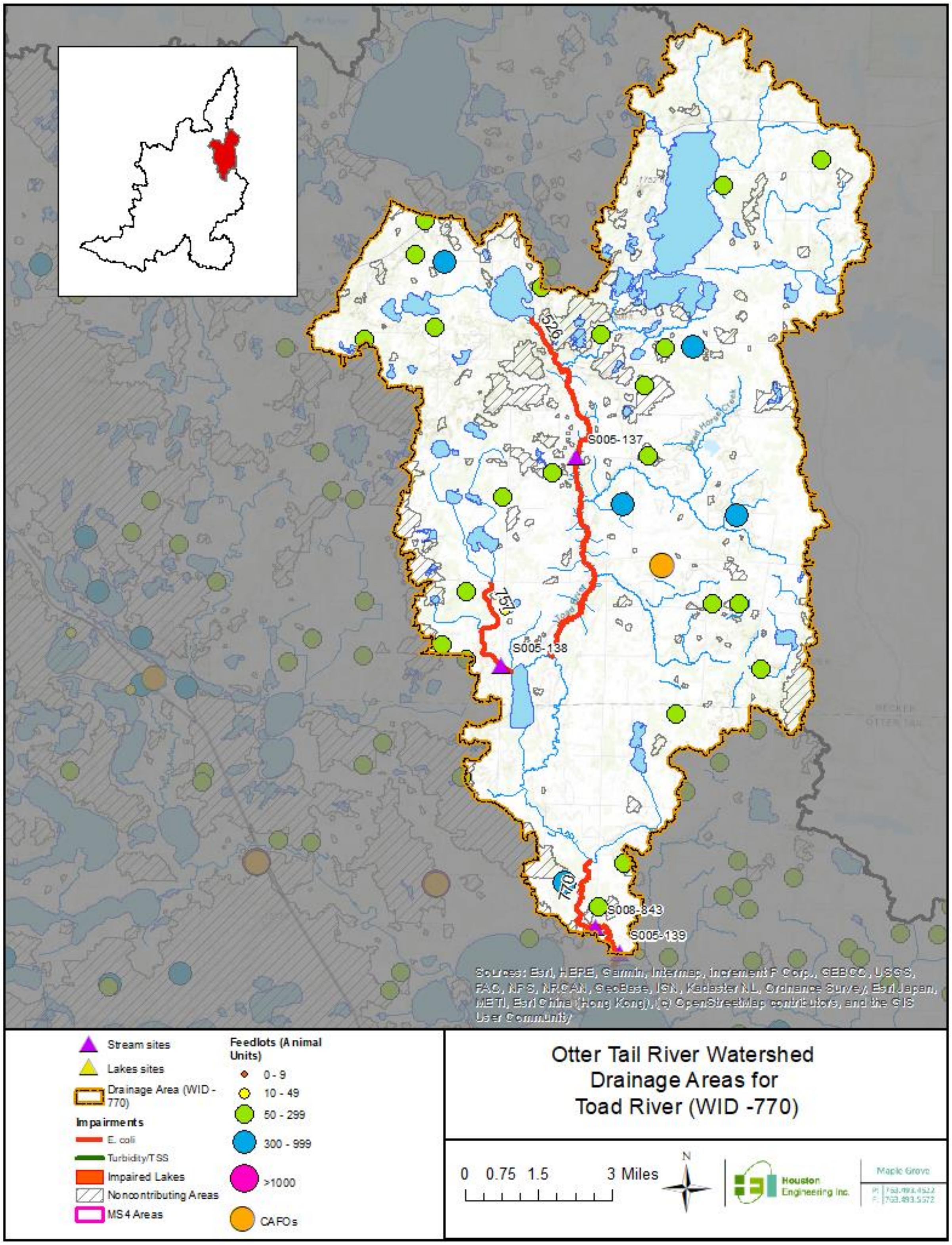

Figure 3. Drainage area of Toad River, Unnamed Creek to Pine Lake (WID 09020103-770).

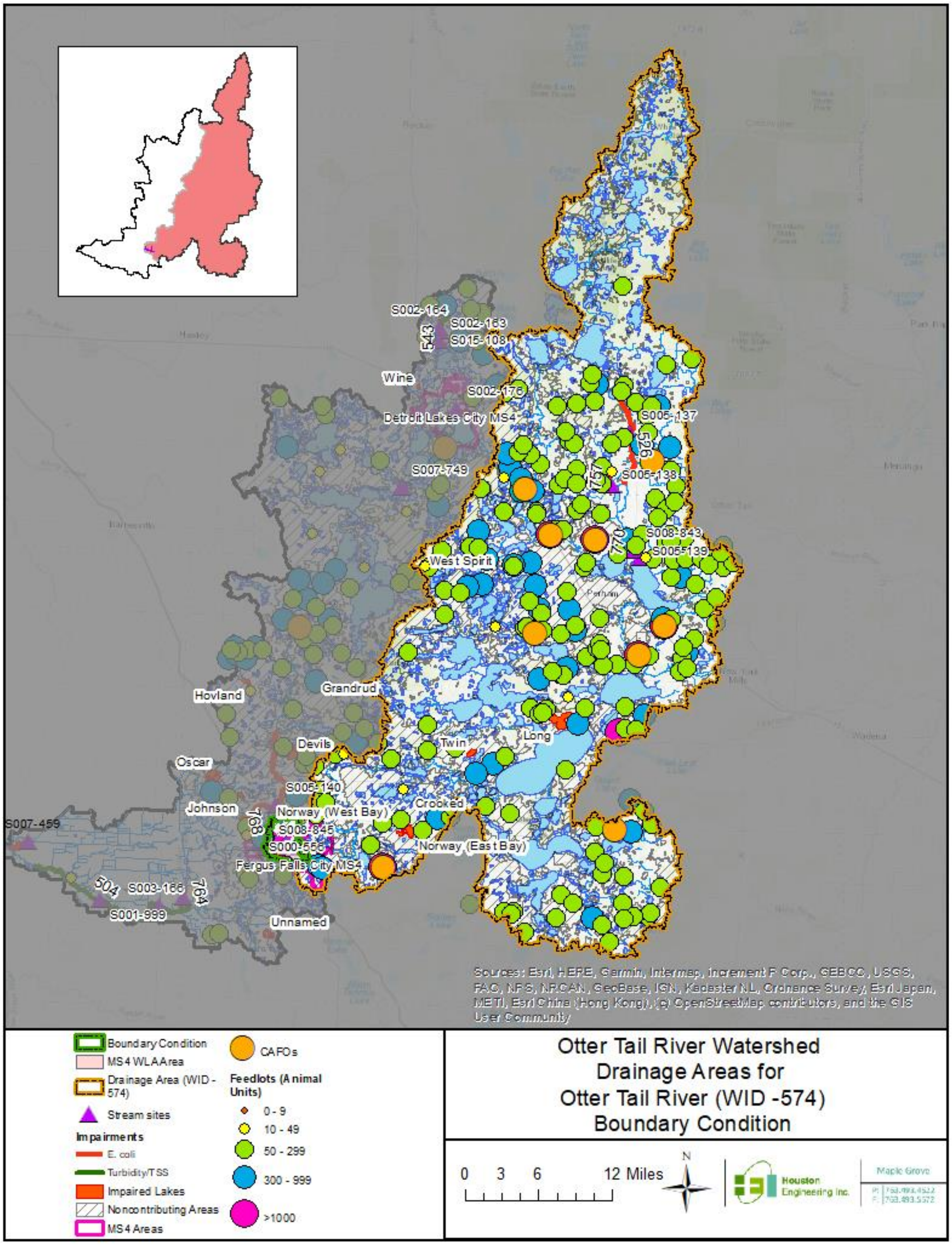

Figure 4. Drainage area of Otter Tail River, Unnamed Lake (56-0821-00) to Pelican River (WID 09020103-574).

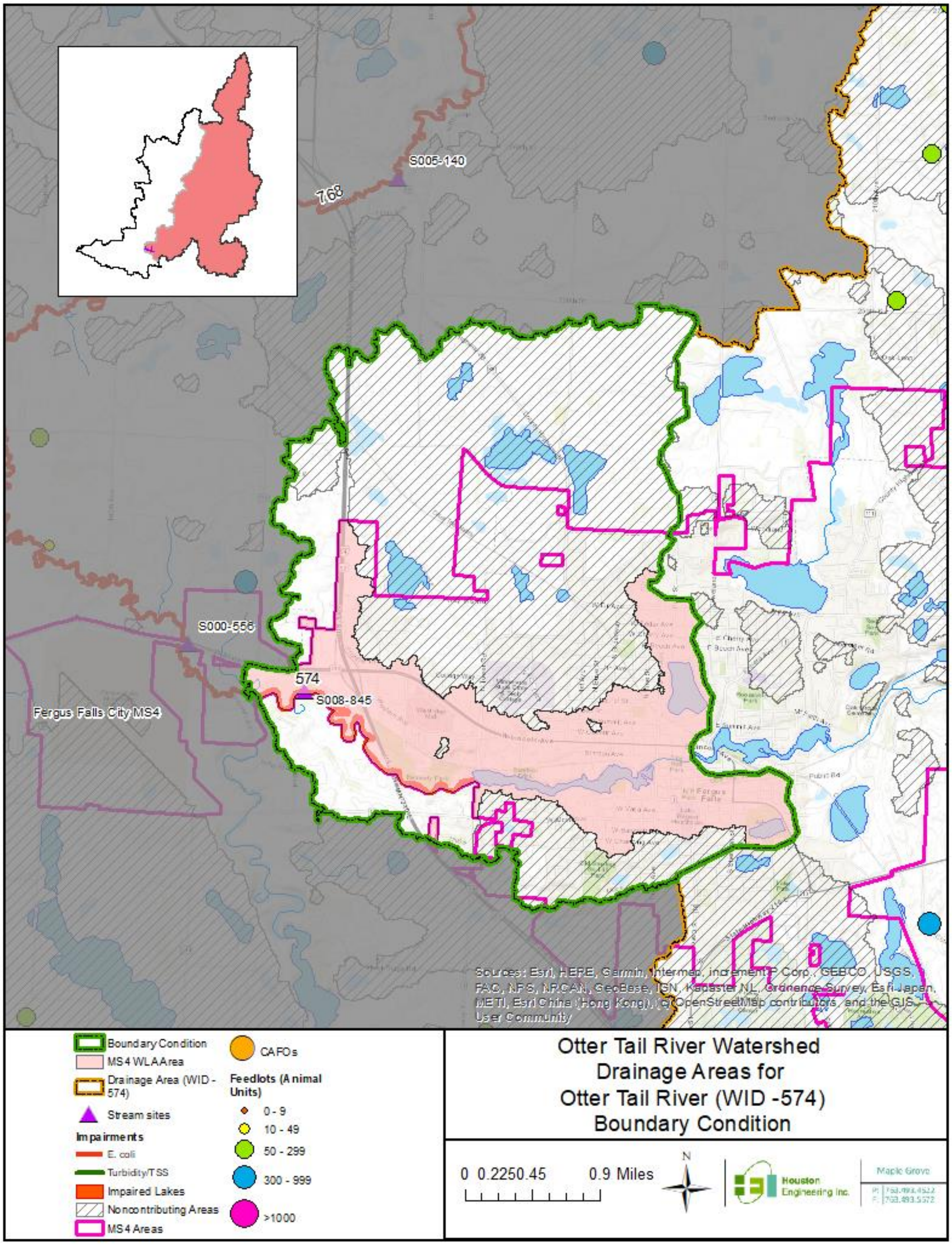

Figure 5. Contributing boundary condition area for Otter Tail River, Unnamed Lake (56-0821-00) to Pelican River (WID 09020103-574).

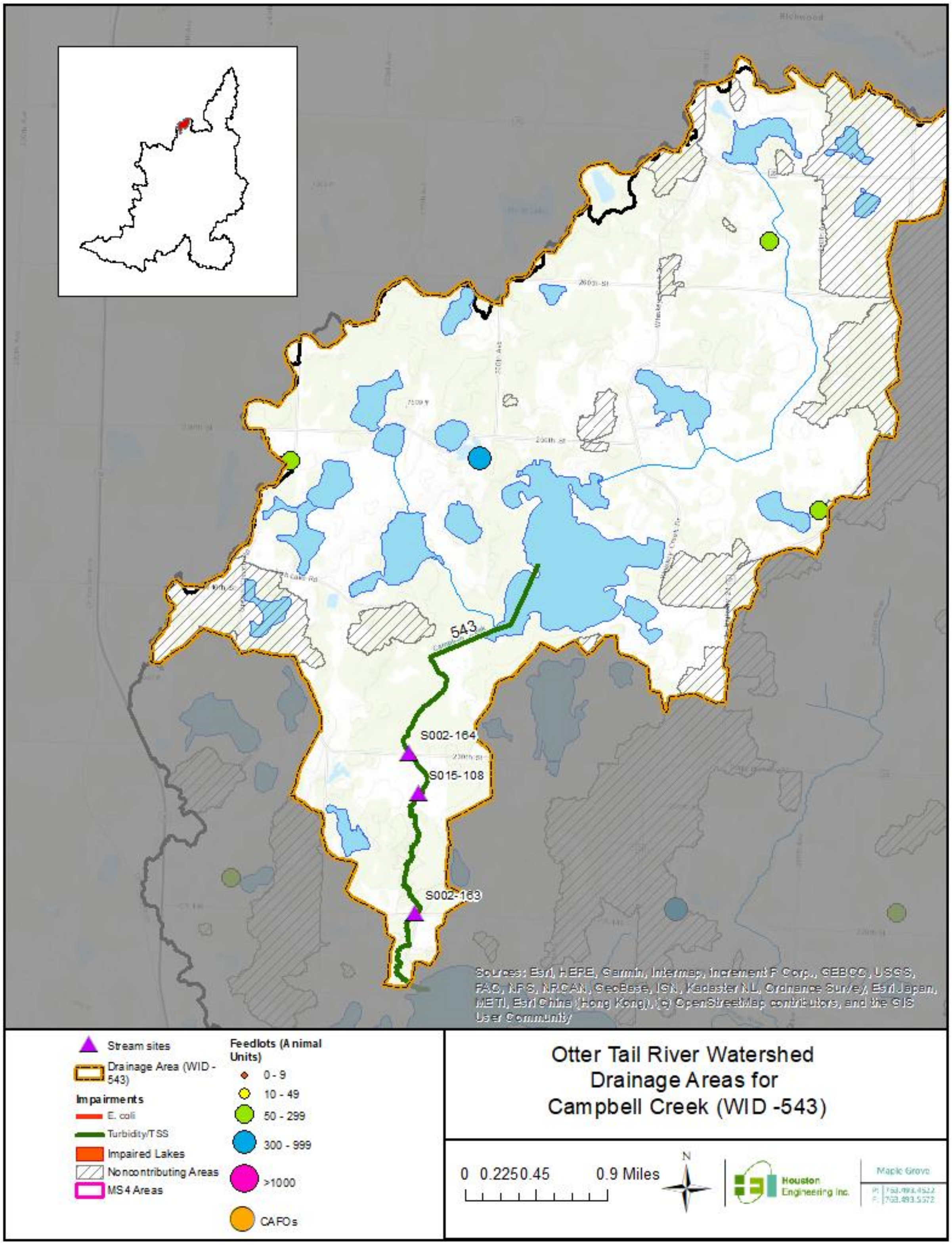

Figure 6. Drainage area of Campbell Creek, Campbell Lake to Floyd Lake (WID 09020103-543).

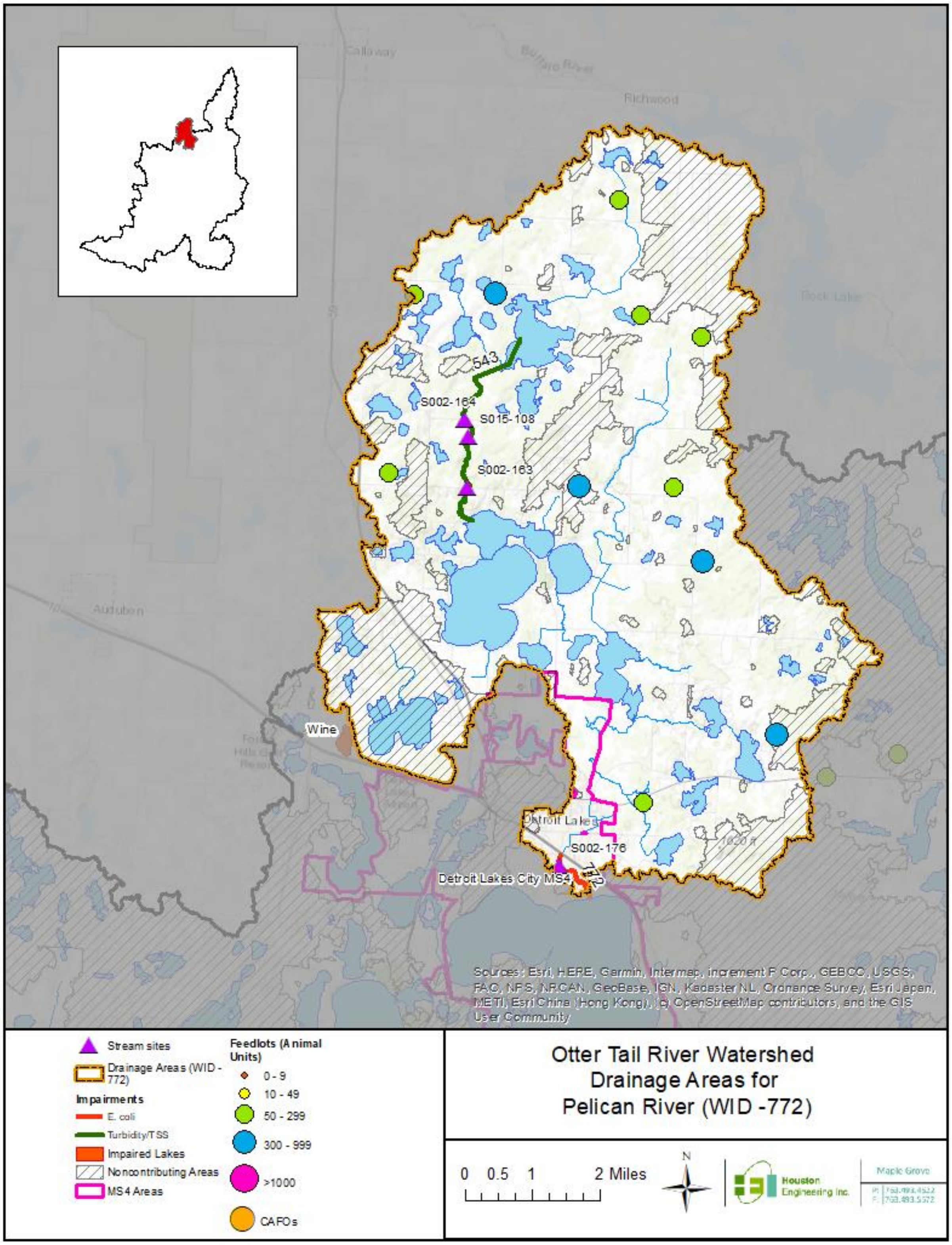

Figure 7. Drainage area of Pelican River, Highway 10 to Detroit Lake (WID 09020103-772).

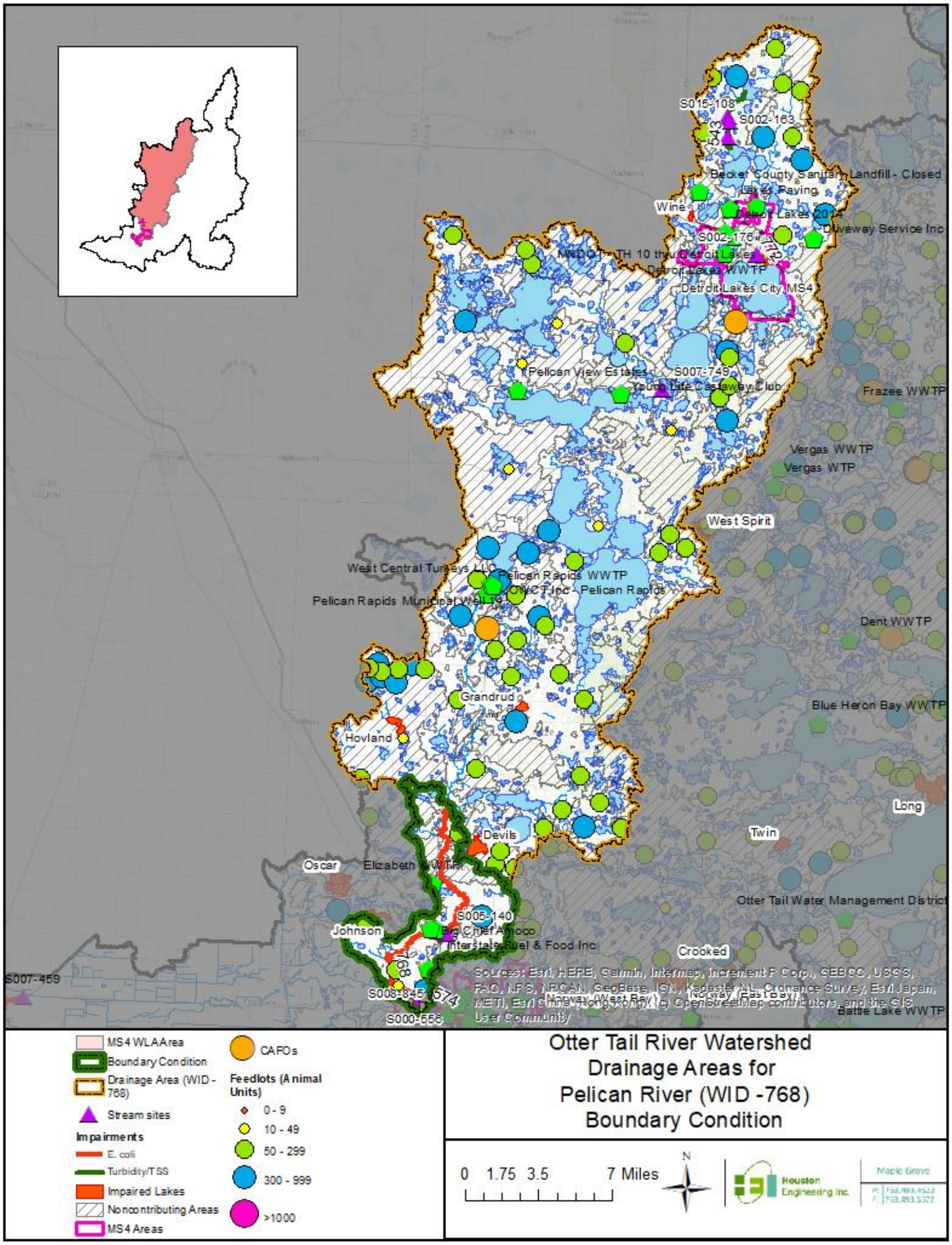

Figure 8. Drainage area of Pelican River, Reed Creek to Otter Tail River (WID 09020103-768).

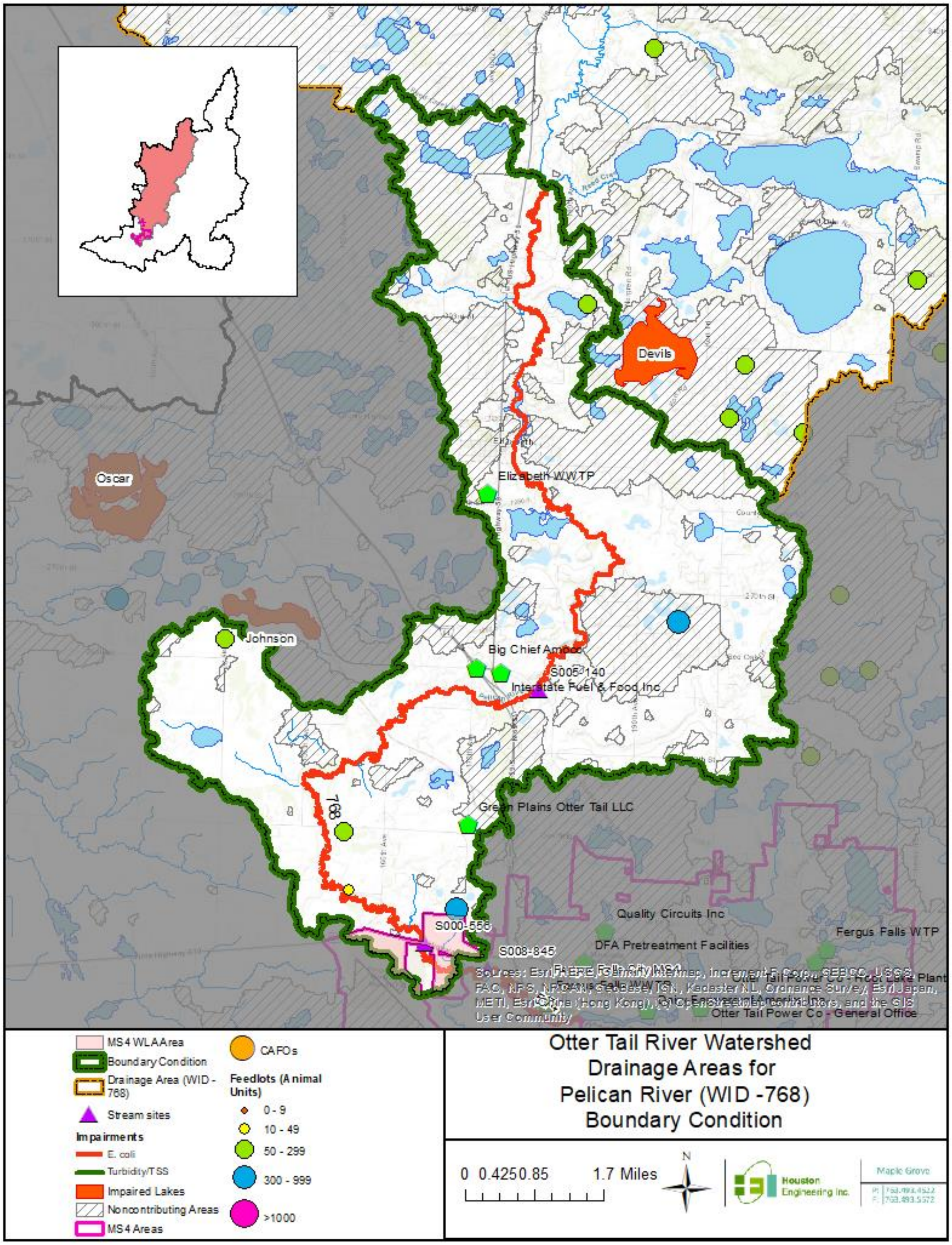

Figure 9. Contributing boundary condition area for Pelican River, Reed Creek to Otter Tail River (WID 09020103-768).

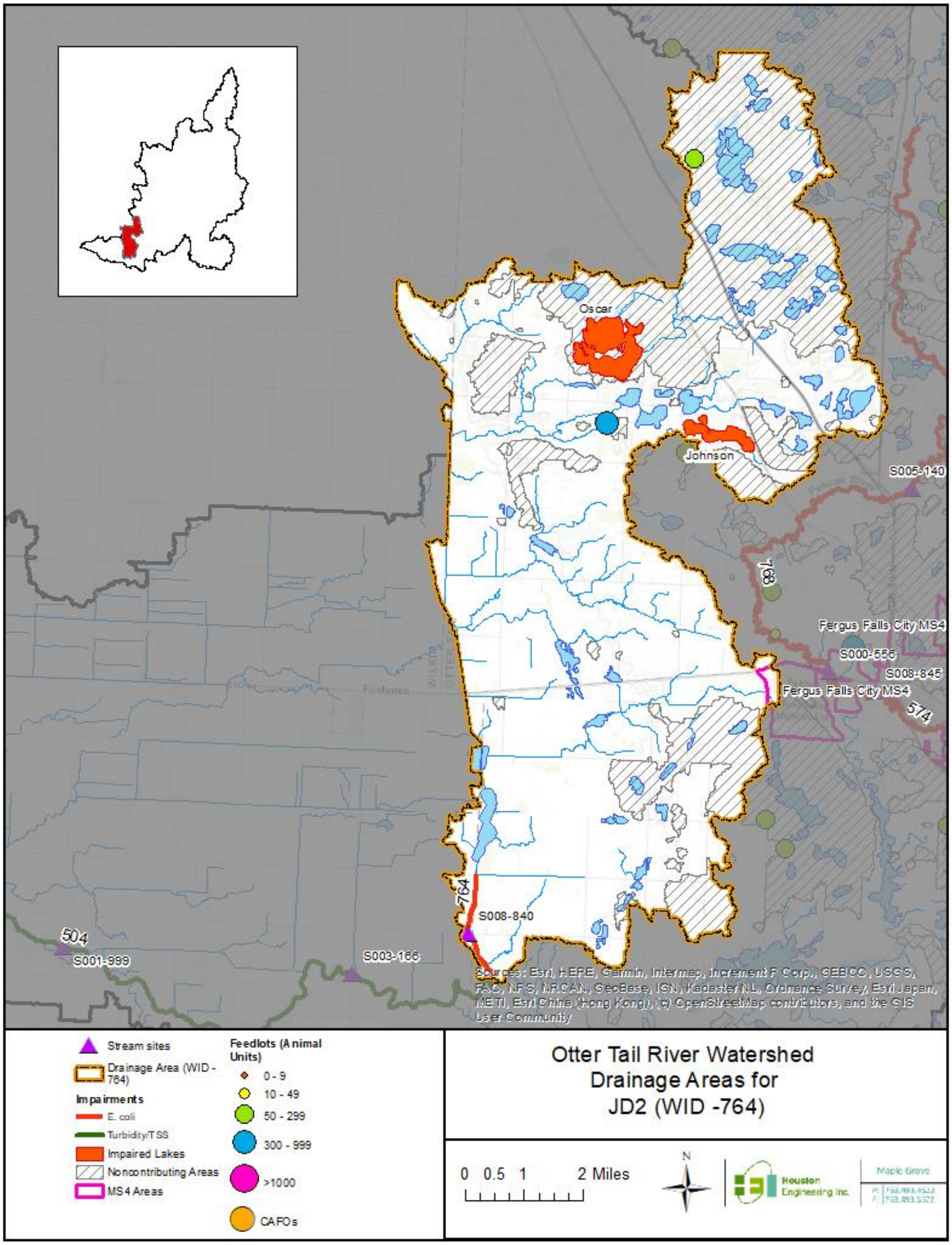

Figure 10. Drainage area of Judicial Ditch 2, Unnamed ditch along 190th St to Otter Tail R. (WID 09020103-764).

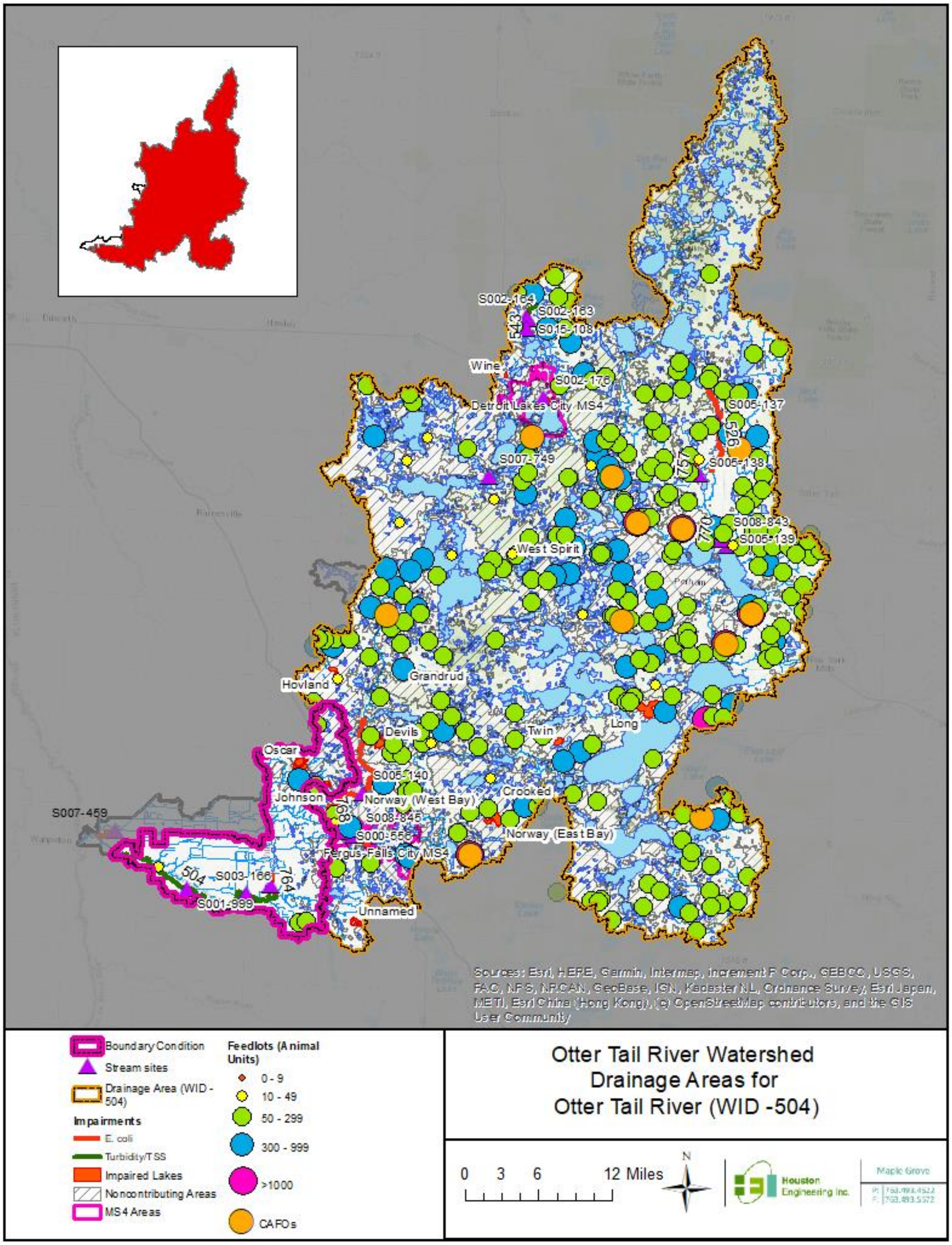

Figure 11. Drainage area of Otter Tail River, Judicial Ditch 2 to Breckenridge Lake (WID 09020103-504).

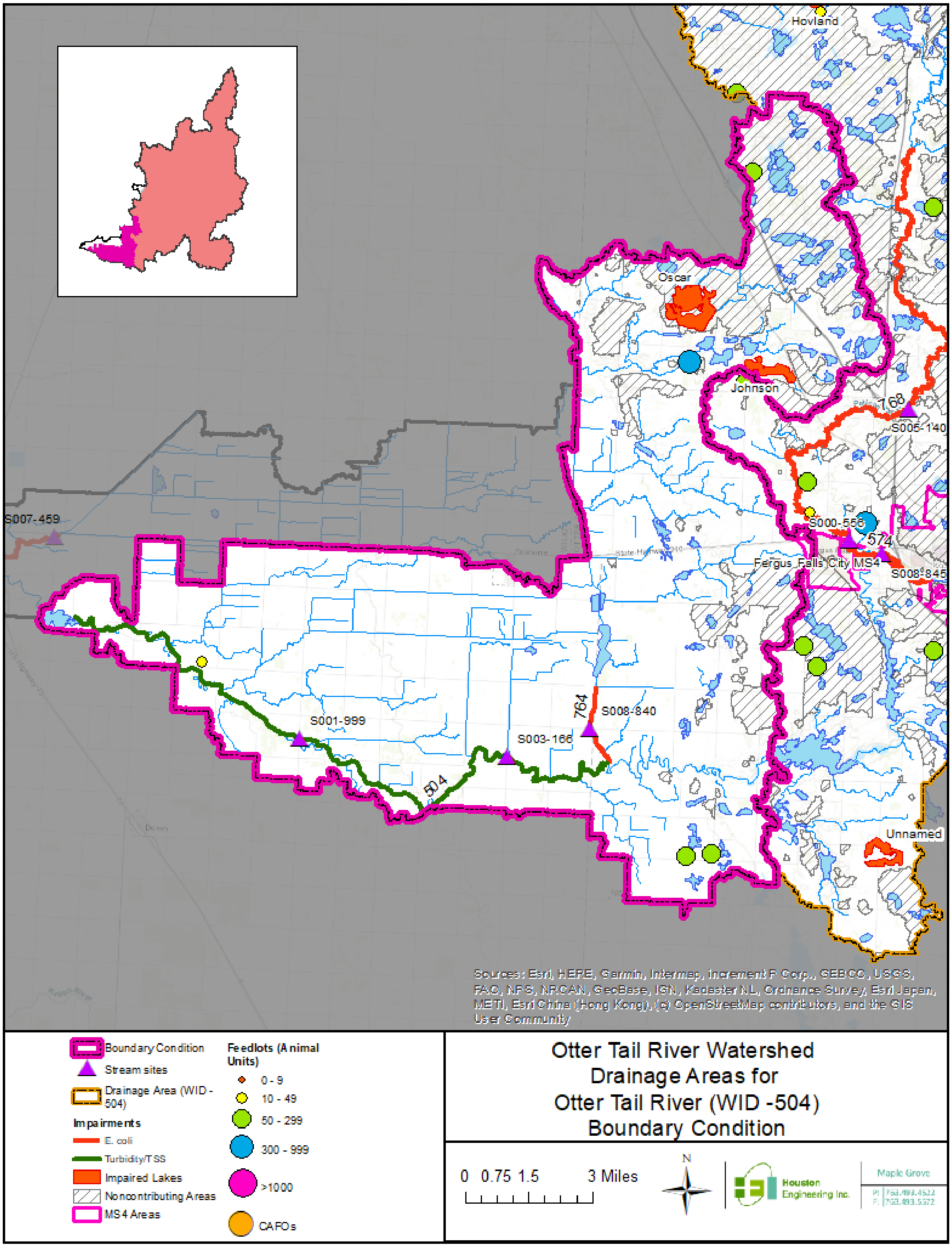

Figure 12. Boundary condition area for Otter Tail River, Judicial Ditch 2 to Breckenridge Lake (WID 09020103-504).

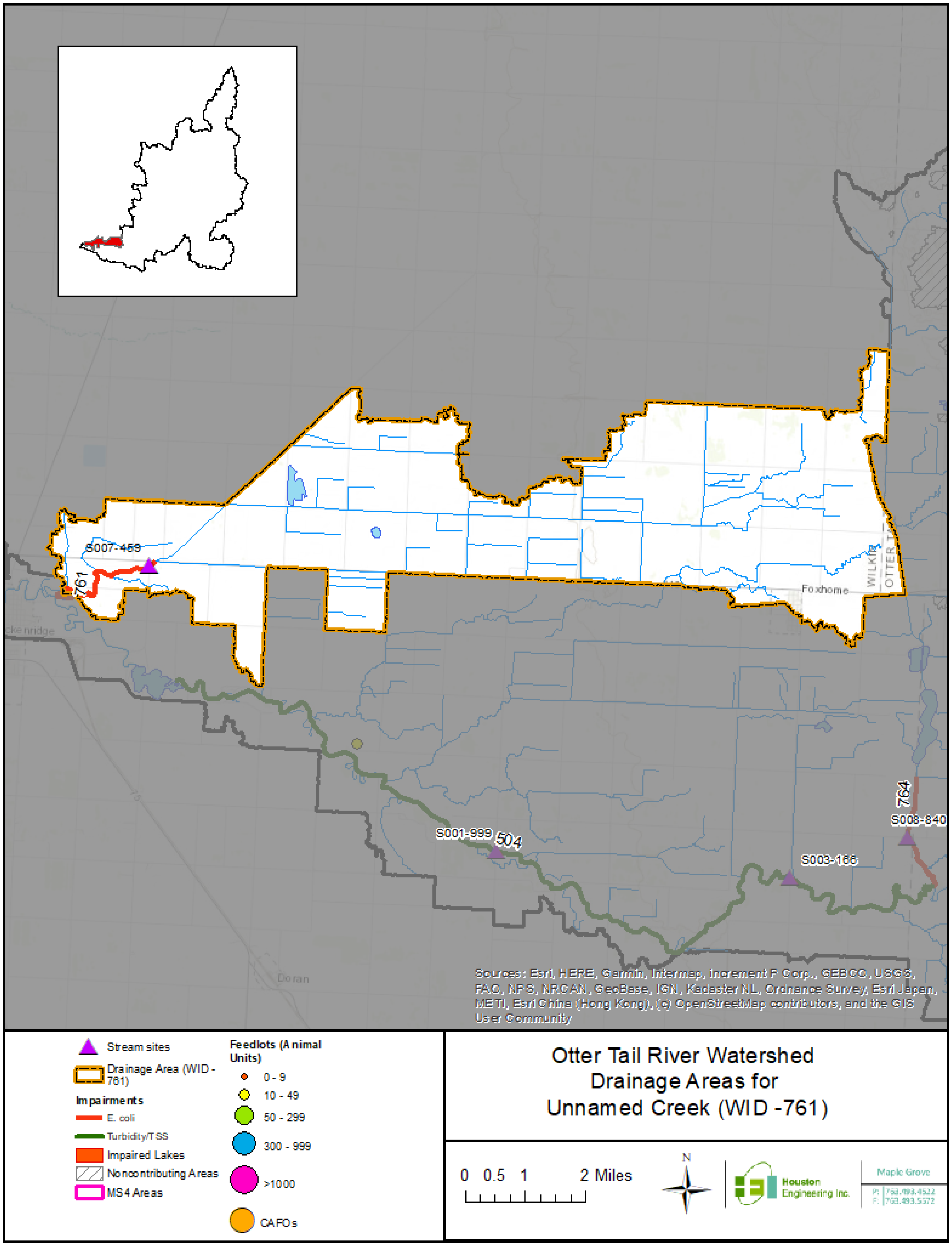

Figure 13. Drainage area of Unnamed Creek, County Ditch 3 to Otter Tail River (WID 09020103-761).

5. BATHTUB Lake Modeling

Introduction

This appendix details the in-lake water quality modeling efforts for impaired lakes in the Otter Tail River Watershed (OTRW) as part of the Minnesota Pollution Control Agency's (MPCA) OTRW's watershed-wide Total Maximum Daily Load (TMDL) Study and Watershed Restoration and Protection Strategies (WRAPS) project. The modeling effort includes impaired lakes in the OTRW (eight-digit hydrologic unit code (HUC) 09020103) needing a TMDL.

The in-lake water quality modeling utilizes a modified version of the BATHTUB model. BATHTUB is a steady-state model that simulates eutrophication-related water quality conditions in lakes and reservoirs. BATHTUB is designed to facilitate the application of empirical eutrophication models to reservoirs or lakes, formulating water and nutrient balances that account for advective transport, diffuse transport, and nutrient sedimentation.

The overall goal of this lake modeling effort is to establish the loading capacities for total phosphorus (TP) in impaired lakes, determine the load reduction needed to meet the water quality standards, and provide information for future management of local water quality. Results of the lake modeling include the predicted average nutrient load reduction required to meet current lake eutrophication water quality standards in each lake. The following describes the data and methodology used to develop the lake models and summarizes the results for each impaired lake.

Impaired Lakes in the Otter Tail River Watershed

Models were developed for thirteen impaired lakes in the OTRW, which are all impaired due to nutrients/eutrophication biological indicators. **Table 1** provides a list of the modeled lakes, along with their eco-region and depth class. **Figure 1** provides the location of these modeled lakes.

Table 1. Impaired Lakes modeled for MPCA's OTRW TMDL Study.

WID	Waterbody Name	Pollutant/Parameter	Designated Use Class[1]	Eco-region	Depth Class[2]	Affected Use[3]	Listing Year[4]
03-0398-00	Wine	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2012
56-0210-00	Long	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0458-00	Crooked	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0502-00	West Spirit	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2008
56-0569-01	Norway (East Bay)	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0569-02	Norway (West Bay)	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0791-00	Unnamed	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0882-00	Devils	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0907-00	Grandrud	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0979-00	Johnson	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-0982-00	Oscar	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-1014-00	Hovland	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020
56-1525-00	Twin	Nutrient/eutrophication biological indicators	2B, 3	NCHF	Shallow	AQR	2020

[1]Designated use classifications and applicable water quality standards are further described in **Section 2** of the OTRW TMDL Report.

[2]Ecoregion and depth classifications and applicable water quality standards are further described in **Section 2.2** of the OTRW TMDL Report.

[3]AQR = aquatic recreation use.

[4]Listing year refers to the year each impairment was first listed on Minnesota's 303(d) Impaired Waters List.

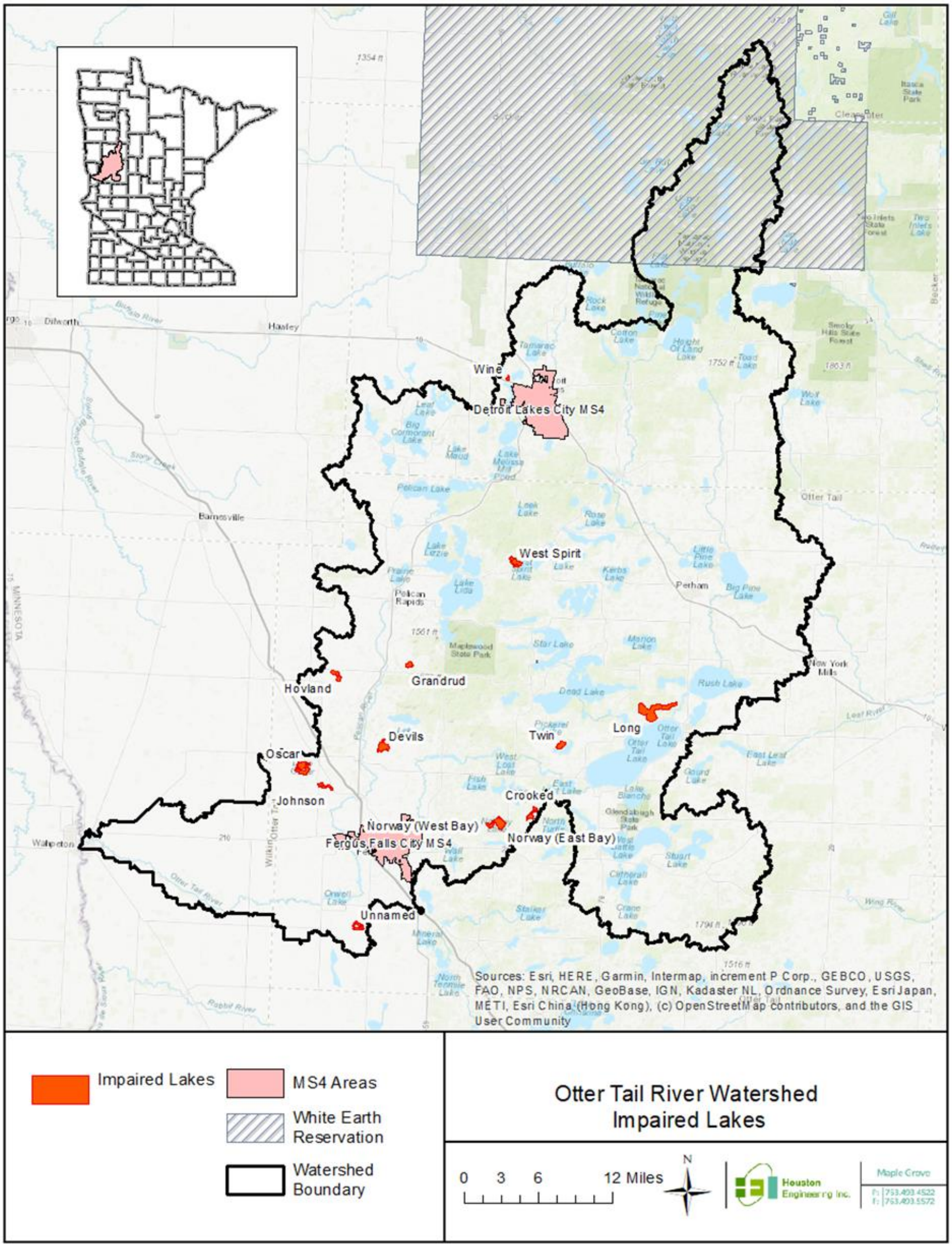

Figure 1. Modeled Lakes in the Otter Tail River Watershed.

Applicable Water Quality Standards and Numeric Water Quality Targets

Lake eutrophication standards are written to protect lakes as a function of their designated beneficial use. The lakes in the OTRW are considered Class 2B waters, which are protected for aquatic life and recreation. Minnesota categorizes its lake water quality standards by ecoregion and depth classification. All impaired lakes addressed in the OTRW TMDL report are in the North Central Hardwood Forest (NCHF) ecoregion and are in the shallow depth class (mean depth less than 15 feet). **Table 2** displays the standards for shallow lakes in the NCHF ecoregion.

Table 2. Surface water quality standards for lakes addressed in the OTRW TMDL report.

Ecoregion	Total Phosphorus	Chlorophyll-*a*	Secchi Disk Depth
North Central Hardwood Forests (NCHF)	Summer (June to September) average not to exceed:		
- Shallow Lakes[1]	60 µg/L[2]	20 µg/L	1.0 meter

[1]Shallow lakes defined as having a mean depth less than 15 feet.
[2]µg/L: micrograms per liter

The MPCA considers a lake impaired when the summer (June to September) average of TP and at least one of the response variables, Chlorophyll-*a* (Chl-*a*) or Secchi disk depth, fail to demonstrate compliance with the standards (MPCA 2018). In addition to meeting TP limits, Chl-*a* and Secchi disk depth standards must also be met for the resource to be considered "fully supporting" of its designated use. In developing the lake nutrient standards for Minnesota lakes (Minn. R. ch. 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (MPCA 2005). Clear relationships were established between the causal factor (TP) and the response variables, Chl-*a* and Secchi disk transparency. Based on these relationships it is expected that by meeting the phosphorus target in each lake, the Chl-*a* and Secchi standards will likewise be met.

In-Lake Water Quality

Water quality data for lakes in the OTRW were obtained from the MPCA through their Environmental Quality Information System (EQuIS) database and Environmental Data Application (EDA) data portal (https://www.pca.state.mn.us/quick-links/eda-surface-water-data). For this modeling effort, the average water quality condition is taken as the period from 1996 through 2018. **Table 3** provides the number of samples and average (mean) measurements during the summer (June through September) for TP, Chl-*a*, and Secchi Disk depths. The lake nutrient impairments are based on summer averages of TP and at least one of the response variables, Chl-*a* or Secchi disk depth, exceeding the standards for NCHF shallow lakes (TP not more than 60 micrograms per liter (µg/L), Chl-a not more than 20 µg/L, and Secchi disk depth not less than 1.0 meter).

Table 3. Current lake nutrients conditions in impaired lakes addressed in the OTRW TMDL report.[1]

Lake Name	WID -Station ID(s)	Observation Period	TP [µg/L]		Chl-*a* [µg/L]		Secchi Disk Depth [m]	
			n	Average	n	Average	n	Average
Wine	03-0398-00-201	2008-2010, 2012	23	**100**	20	**30**	22	**0.779**
Long	56-0210-00-201, 56-0210-00-202	2016-2018	23	**126**	23	**54**	24	**0.464**
Crooked	56-0458-00-201	2011-2012	10	**83**	10	**58**	10	**0.850**
West Spirit	56-0502-00-201	2000-2007	38	**72**	38	**28**	38	1.138
Norway (East Bay)	56-0569-01-100, 56-0569-01-201	2011-2012, 2017-2018	20	**132**	20	**29**	46	3.083
Norway (West Bay)	56-0569-02-201	2011-2012	10	**162**	10	**31**	10	1.800
Unnamed	56-0791-00-201, 56-0791-00-202	2011-2012, 2014	11	**197**	11	**109**	11	**0.355**
Devils	56-0882-00-201	2011-2012	10	**100**	10	**50**	10	1.210
Grandrud	56-0907-00-201	2011-2012	11	**61**	11	**25**	10	**0.740**
Johnson	56-0979-00-201	2011-2012	10	**98**	10	**46**	10	**0.420**
Oscar	56-0982-00-202	2003, 2008, 2011-2012	10	**151**	8	**54**	10	1.172
Hovland	56-1014-00-201	2011-2012	12	**185**	12	**43**	10	1.530
Twin	56-1525-00-201	2011-2012	10	**140**	10	**61**	9	**0.522**

[1]Bold entries denote averages that exceed standard.

Model Development

Two models were used to develop the lake water quality estimates and TMDL components for lakes in the OTRW. The Hydrologic Simulation Program-FORTRAN (HSPF) watershed model was used to provide surface runoff and TP loadings to the lakes. In-lake water quality was modeled using a modified version of the BATHTUB model, developed for use with a spreadsheet program (e.g. EXCEL). Load reduction scenarios were developed for each lake to estimate the required load reduction needed to meet current lake eutrophication water quality standards. The following provides a summary of the watershed models, lake models, input data, and mass balances.

Watershed Model

The flow and nutrient loadings were extracted for the HSPF watershed model. The HSPF model is a comprehensive package for simulation of watershed hydrology, sediment transportation, and water quality for conventional and toxic organic pollutants. HSPF incorporates the watershed-scale Agricultural Runoff Model (ARM) and nonpoint source (NPS) models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. It is a comprehensive model of watershed hydrology and water quality that allows the integrated simulation of point sources, land and soil contaminant runoff processes, along with in-stream hydraulic and sediment-chemical interactions. The result of this simulation is a time history of the runoff flow rate, sediment load, nutrient and pesticide concentrations, and water quantity and quality at the outlet of any subwatershed. The hydrologic/nutrient budget components taken from the HSPF model include precipitation, potential evapotranspiration (assumed to be equal to evaporation), contributing drainage area runoff volume, contributing drainage area phosphorus loads, tributary flow, and tributary phosphorus loads.

Modeling results from the OTRW's HSPF model (TetraTech 2017) were used to develop the inputs to the in-lake water quality BATHTUB models. Data from the ORTW HSPF model were available from 1996 through 2014 for daily, monthly, and annual timescales at the sub-basin scale.

In-lake Water Quality Model

In-lake water quality was simulated using a spreadsheet version of the BATHTUB model currently available as a "beta" version from Dr. William W. Walker (URL: http://www.wwwalker.net/bathtub/index.htm). BATHTUB is a steady-state model that simulates eutrophication-related water quality conditions in lakes and reservoirs. The BATHTUB models are designed to facilitate the application of empirical eutrophication models to reservoirs or lakes, formulating water and nutrient balances that account for advective transport, diffuse transport, and nutrient sedimentation.

Lake Morphology

The required inputs to the lake models include basic morphology characteristics such as surface area, mean depth, and drainage area. **Table 4** lists the required morphometric characteristics for the modeled lakes in the OTRW. The morphometric characteristics displayed in **Table 4** are in U.S. customary units and are converted to the international system of units (SI) (i.e., the metric system) for use in the lake models. The primary data sources used for lake morphometric characteristics were the MN DNR LakeFinder website (http://www.dnr.state.mn.us/lakefind/index.html) and the OTRW Monitoring and Assessment Report (MPCA 2019a).

Table 4. Lake Morphology in modeled lakes in Otter Tail River Watershed.

Lake Name	WID	Surface Area [acres]	Average Depth [feet]	Max depth [feet]	Drainage Area [acres]
Wine	03-0398-00	31.2	3	5.5	169
Long	56-0210-00	1,092	5	16	2,787
Crooked	56-0458-00	132	7	20	1,203
West Spirit	56-0502-00	261	6	18	556
Norway (East Bay)	56-0569-01	314	6	19	996
Norway (West Bay)	56-0569-02	93.0	6	19	2,222
Unnamed	56-0791-00	140	4	10.5	761
Devils	56-0882-00	308	6	18	1,632
Grandrud	56-0907-00	113	7	21	553
Johnson	56-0979-00	154	2	3	1,186
Oscar	56-0982-00	337	3	6	9,421
Hovland	56-1014-00	181	7	20	2,071
Twin	56-1525-00	181	4	10	802

Water Mass Balance

A lake's water mass balance, or water budget, is an accounting of the amount of water entering and leaving a lake over a given time period. This modeling effort assumes an annual time period for modeling the lakes in the ORTW. The hydrologic residence time is less than one year. The amount of water moving in and out of a system varies from year-to-year, dictated primarily by the seasonal variation of precipitation occurring in the area. It is important to quantify the water budget because different sources of water can contain different quantities of pollutants, and the amount of water entering and leaving the lake determines the hydraulic residence time, which impacts the lake's eutrophication response. Additionally, the water budget is important because it is used during hydrologic and water quality modeling for model calibration and validation purposes. A water budget accounts for "gains" in water to the lake (e.g., precipitation, surface water runoff, tributary inflow, advection flow, or groundwater inflow) as well as "losses" (e.g., evaporation, surface outflow, and groundwater outflow). Each of these affects the volume of water in the lake (i.e., storage).

The water budget components accounted for in this study are: **Precipitation**, the amount of water entering the lake directly from precipitation landing on the lake's surface; **Direct drainage inflow**, the water flowing to the lake from the contributing drainage area, including both surface and groundwater inputs; **Tributary inflow**, the amount of water flowing into the lake from upstream basins, usually from stream sources; **Evaporation**, the water leaving the surface of the lake through evaporative processes; **Surface outflow**, the water leaving the lake through surface outlets (usually a stream); and **Storage**, the change in the water stored in the lake due to lake level increases or decreases. Any groundwater flows are lumped into direct drainage, tributary flow, and/or outflow. The lake models are steady-state models, meaning change in storage is zero.

The water mass balance summary for each modeled lake is provided in the model summaries tables at the end of this Appendix.

Phosphorus Mass Balance

Similar to a water budget, a TP mass balance accounts for the amount of TP entering and exiting a lake over a given time period. TP amounts are expressed as loads, in units of mass per time, or for the purposes of this study, pounds per year (lbs/year). The nutrient loads are estimated by considering the concentration of TP in the water and the amount of water entering and exiting the lake over the time period. The TP mass balance accounts for both "gains" (e.g., surface water runoff) as well as "losses" (e.g., outflows) from the lake. A typical lake TP mass balance accounts for direct drainage area loading, tributary loading, atmospheric deposition, internal loading, sedimentation/retention, advection, dispersion, and outflow. Each of the phosphorus mass balance components is discussed in more detail below.

Direct Drainage Loading

The amount of phosphorus entering each lake from its direct drainage (non-tributary) was estimated using the outputs of the HSPF model. Phosphorus loads for the sub-basins containing each lake were extracted from the model. Since no modeled lakes were explicitly modeled in the OTRW HSPF model, the TP loadings were extracted from the hydrologic response units (HRUs) within the lakeshed of the modeled lake.

Atmospheric Loading

The rates of atmospheric deposition of phosphorus onto each of the simulated lakes were set equal to those found in the MPCA's state-wide phosphorus study, more specifically the 2007 atmospheric deposition update (Barr 2007). An estimated total deposition rate of an average year for the Red River

Valley (Red River of the North Basin Watershed) of 26.1 kg/ha/year was used for modeling atmospheric deposition to the lakes.

Potential Internal Loading

Internal loading is the re-release of TP from sediments, which is typically due to multiple mechanisms such as anoxic conditions (Dissolved Oxygen concentrations < 2.0 mg/L) near the bed of the lake, bottom-feeding fish, such as bullhead and carp, foraging in and disturbing lake sediments, and other physical disturbances in shallow depths, such as wave action from wind energy and motorized boats. Internal phosphorus loading can be a substantial part of the mass balance in a lake, especially in lakes with a history of high phosphorus loads. If a lake has a long history of high phosphorus concentrations, it is possible to have internal loading rates higher than external loads. There was no information on specific internal loading in lakes in the OTRW at the time of the OTRW TMDL Report, therefore, internal loading rates (if needed) were determined using two mass balance approaches. First, a mass balance approach developed by Nurnberg (1984) to check if an "additional" internal load is necessary to meet in-lake phosphorus concentrations. Second, if the Nurnberg equation showed the need for an "additional" load, the internal loads were used to calibrate the BATHTUB models, i.e., additional loads were added to the lake models until in-lake phosphorus concentrations were met.

The need for an "additional" Internal load was checked using methodology developed by Nurnberg (1984) referred to as the mass balance approach. Internal loading is estimated by adding an internal loading term to the current models based on external loading and predicted retention (Nurnberg 1984):

$$TP = {}^{L_{ext}}\!/_{q_s}\left(1 - R_{pred}\right) + {}^{L_{int}}\!/_{q_s} \qquad [1]$$

where TP is the in-lake TP concentration (µg/L); L_{ext} is the external load (kg/yr), q_s is the lake outflow (hm^3/yr), R_{pred} is the predicted retention coefficient, and L_{int} is the internal loading (kg/yr). The retention coefficient can be estimated using:

$$R_{pred} = {}^{15}\!\Big/_{\left(18 + {}^{q_s}\!/_{A}\right)} \qquad [2]$$

where A = surface area of the lake (km^2). The only unknown in [1] and [2] is internal loading and it can be estimated by solving for L*int*.

Using equations [1] and [2], and given external loading rates (from HSPF), the potential for internal loading was checked for the modeled lakes. All modeled lakes showed the need for an explicit internal load.

Next, the BATHTUB phosphorus model was set to the Canfield and Bachman Natural Lakes model and the calibration coefficient was set to one. Additional phosphorus loads were added to the lake models until modeled in-lake phosphorus concentrations matched the observed data. It should be noted, these estimated "additional" internal loads include the lakes' internal loading, any unknown or unquantified loads that were not included in the currently available data (e.g. additional, unidentified loading from septic systems, surface loading, and/or animal feedlot runoff), and any model uncertainty.

Table 5 provides the estimated internal loads, an annualized internal loading rate (averaged over a 365-day calendar year), and the percentage of total load to a lake from internal loading. All lakes showed the need for an “additional” load using the Nurnberg methodology, but when estimating the internal loading in BATHTUB, Johnson Lake showed no need for an additional load. It is assumed that any internal loading in Johnson Lake is covered by the internal loading implicitly included in the BATHTUB model equations and no “additional” loading was required for the Johnson Lake model to match the observed in-lake TP data.

Table 5. Estimated internal loading rates in the impaired lakes addressed in the OTRW TMDL Report.

Lake Name	WID	Existing P Load [lbs/yr]	Estimated Internal loading [lbs/yr]	Internal loading yields [mg/m2/day]	Percent of total load
Wine	03-0398-00	78	41	0.41	52.6%
Long	56-0210-00	4,294	3,710	1.04	86.4%
Crooked	56-0458-00	468	227	0.53	48.5%
West Spirit	56-0502-00	426	322	0.38	75.6%
Norway (East Bay)	56-0569-01	1,507	1,314	1.29	87.2%
Norway (West Bay)	56-0569-02	1,229	800	2.64	65.1%
Unnamed	56-0791-00	1,069	809	1.78	75.7%
Devils	56-0882-00	1,148	800	0.80	69.7%
Grandrud	56-0907-00	210	116	0.31	55.2%
Johnson	56-0979-00	333	0	0	0.0%
Oscar	56-0982-00	3,487	1,323	1.21	37.9%
Hovland	56-1014-00	2,587	2,048	3.48	79.2%
Twin	56-1525-00	806	607	1.03	75.4%

Surface Outflow Loading

The amount of TP exiting each lake through surface water outflow is known as surface outflow load and was calculated by taking the in-lake TP concentration and applying it to the lake’s outflow.

Summary of phosphorus mass balances

The phosphorus mass balances were estimated using the BATHTUB model with forcing data from the HSPF models. The phosphorus mass balances for the modeled lakes are found in the model summary tables at the end of this Appendix.

Model Application

The following provides a summary of the lake model application, including calibration and load reduction scenarios.

Model Calibration

The BATHTUB model relies on a variety of sub-models (i.e., empirical equations for estimating sedimentation) for computing eutrophication dynamics within a lake, providing the ability to simulate eutrophication dynamics in lakes with differing in-lake processes. Since no specific internal loading information is available for any modeled lakes, the internal loading rates for the average condition was used to calibrate the models. If no “additional” internal loading was needed, the calibration coefficients were used to calibrate the lake response models (Johnson Lake). The modeling period for the lake models was 1996 through 2014. All available in-lake water quality data was used in calibrating the lake models; the models were calibrated to the period-averaged condition, and individual years were used to validate the models. The average condition was used to calibrate the models due to differing years of available water quality data between monitoring sites and determine the average internal loading conditions. The calibrated internal loading rates and coefficients are summarized in the model summary tables below.

Load Reduction Scenarios

The purpose of this lake modeling effort is to determine the loading scenario(s) under which applicable water quality standards will be met in the impaired lakes addressed in the OTRW TMDL Report and to be used to improve the in-lake water quality conditions. For the load reduction scenarios, TP loadings were reduced incrementally within the BATHTUB model. It is assumed that all load reductions come from the contributing drainage area and internal loading/unknown sources, except for Johnson Lake. Only an overall load reduction is determined in the lake model summary tables below; the individual TMDL tables for the impaired lakes addressed in the OTRW TMDL Report include an overall reduction, a total nonpoint load reduction, and specific reductions for nonpoint sources vs. internal loading/unknown sources.

This approach is consistent with MPCA guidance (MPCA 2007), which assumes that if a lake meets the state's TP water quality standard, that Chl-*a* and Secchi disk depth within the system will respond accordingly and eventually also reach the state-defined goals. This approach assumes that data collected and extensively analyzed by the MPCA during standards development provides a more accurate estimate of how lakes will respond when moved from an impaired to unimpaired state than the relationships that exist within the BATHTUB model. The load reductions are summarized in the model summary tables below and further discussed in **Section 4.4.6** of the OTRW TMDL Report.

Model Summaries

Table 6. Lake Model Summary for Wine Lake (03-0398-00).

Lake Name:	Wine		**WID:**	03-0398-00	
Eco-region:	NCHF		**Depth Class:**	Shallow	

Models, Calibration Coefficients, and Predicted & Observed Values

Parameter	Model	Calibration Coefficient	Observed	Predicted	Units
Phosphorus	CB-LAKES	1.00	100.3	100.3	ppb

Overall Water and Nutrient Balances

Overall Water Balance		Averaging Period =		1	years
	Flow	**Units**	**%Total**		
Precipitation Flow	0.09	hm3/yr	44.2%		
Specified Flow	0.11	hm3/yr	55.8%		
NonPoint Flow	0.00	hm3/yr	0.0%		
Point Flow	0.00	hm3/yr	0.0%		
Total Inflow	0.20	hm3/yr	100.0%		
Evaporation	0.11	hm3/yr	52.7%		
Outflow	0.10	hm3/yr	47.3%		
Overall Phosphorus Mass Balance					
	Load		**%Total**	**Conc.**	
Precipitation Load	3.3	kg/yr	9%	37	ppb
Specified Load	13.5	kg/yr	38%	119	ppb
Internal Loading	18.7	kg/yr	53%	0	ppb
Point Load	0.0	kg/yr	0%	0	ppb
Total Load	35.5	kg/yr	100%	175	ppb
Sedimentation	25.9	kg/yr	73%		ppb
Outflow	9.6	kg/yr	27%	100	ppb

Model Information

Reservoir Volume (hm3):	0.116	Retention Coefficient:	0.729
Hydraulic Residence Time (yrs):	1.203	Reservoir P Conc (ppb):	100.3
Overflow Rate (m/yr):	0.76	Mass Residence Time (yrs):	0.1544
Inflow P Conc (ppb):	370	Turnover Ratio:	6.5

Reductions

Needed Reduction (overland & internal loading):	58.3%	46.96 lbs/yr

Table 7. Lake modeling summary for Long Lake (56-0210-00).

Lake Name:	Long		**WID:**	56-0210-00	
Eco-region:	NCHF		**Depth Class:**	Shallow	
Models, Calibration Coefficients, and Predicted & Observed Values					
Parameter	**Model**	**Calibration Coefficient**	**Observed**	**Predicted**	**Units**
Phosphorus	CB-LAKES	1.00	125.8	127.4	ppb
Overall Water and Nutrient Balances					
Overall Water Balance		Averaging Period =		1	years
	Flow	**Units**	**%Total**		
Precipitation Flow	3.07	hm3/yr	69.4%		
Specified Flow	1.35	hm3/yr	30.6%		
NonPoint Flow	0.00	hm3/yr	0.0%		
Point Flow	0.00	hm3/yr	0.0%		
Total Inflow	4.42	hm3/yr	100.0%		
Evaporation	3.75	hm3/yr	84.9%		
Outflow	0.67	hm3/yr	15.1%		
Overall Phosphorus Mass Balance					
	Load		**%Total**	**Conc.**	
Precipitation Load	115.3	kg/yr	6%	38	ppb
Specified Load	149.3	kg/yr	8%	110	ppb
Internal Loading	1683.0	kg/yr	86%	0	ppb
Point Load	0.0	kg/yr	0%	0	ppb
Total Load	1947.6	kg/yr	100%	440	ppb
Sedimentation	1862.4	kg/yr	96%		ppb
Outflow	85.2	kg/yr	4%	127	ppb
Model Information					
Reservoir Volume (hm3):	6.732		Retention Coefficient:		0.956
Hydraulic Residence Time (yrs):	10.070		Reservoir P Conc (ppb):		127.4
Overflow Rate (m/yr):	0.15		Mass Residence Time (yrs):		0.0666
Inflow P Conc (ppb):	2913		Turnover Ratio:		15.0
Reductions					
Needed Reduction (overland & internal loading):		78.0%	3,322.23 lbs/yr		

Table 8. Lake modeling summary for Crooked Lake (56-0458-00).

Lake Name:	Crooked		**WID:**	56-0458-00	
Eco-region:	NCHF		**Depth Class:**	Shallow	
<u>Models, Calibration Coefficients, and Predicted & Observed Values</u>					
Parameter	**Model**	**Calibration Coefficient**	**Observed**	**Predicted**	**Units**
Phosphorus	CB-LAKES	1.00	82.6	82.6	ppb
<u>Overall Water and Nutrient Balances</u>					
Overall Water Balance		Averaging Period =		1	years
	Flow	**Units**	**%Total**		
Precipitation Flow	0.36	hm3/yr	35.2%		
Specified Flow	0.66	hm3/yr	64.8%		
NonPoint Flow	0.00	hm3/yr	0.0%		
Point Flow	0.00	hm3/yr	0.0%		
Total Inflow	1.01	hm3/yr	100.0%		
Evaporation	0.46	hm3/yr	45.7%		
Outflow	0.55	hm3/yr	54.3%		
Overall Phosphorus Mass Balance					
	Load		**%Total**	**Conc.**	
Precipitation Load	13.9	kg/yr	7%	39	ppb
Specified Load	95.5	kg/yr	45%	146	ppb
Internal Loading	103.0	kg/yr	48%	0	ppb
Point Load	0.0	kg/yr	0%	0	ppb
Total Load	212.4	kg/yr	100%	210	ppb
Sedimentation	167.1	kg/yr	79%		ppb
Outflow	45.4	kg/yr	21%	83	ppb
<u>Model Information</u>					
Reservoir Volume (hm3):	1.138		Retention Coefficient:		0.786
Hydraulic Residence Time (yrs):	2.073		Reservoir P Conc (ppb):		82.6
Overflow Rate (m/yr):	1.03		Mass Residence Time (yrs):		0.2402
Inflow P Conc (ppb):	387		Turnover Ratio:		4.2
<u>Reductions</u>					
Needed Reduction (overland & internal loading):		41.6%	225 lbs/yr		

Table 9. Lake modeling summary for West Spirit Lake (56-0502-00).

Lake Name:	West Spirit		**WID:**	56-0502-00	
Eco-region:	NCHF		**Depth Class:**	0	

Models, Calibration Coefficients, and Predicted & Observed Values

Parameter	Model	Calibration Coefficient	Observed	Predicted	Units
Phosphorus	CB-LAKES	1.00	72.0	72.0	ppb

Overall Water and Nutrient Balances

Overall Water Balance Averaging Period = 1 years

	Flow	Units	%Total
Precipitation Flow	0.75	hm3/yr	75.1%
Specified Flow	0.25	hm3/yr	24.9%
NonPoint Flow	0.00	hm3/yr	0.0%
Point Flow	0.00	hm3/yr	0.0%
Total Inflow	1.00	hm3/yr	100.0%
Evaporation	0.89	hm3/yr	89.5%
Outflow	0.11	hm3/yr	10.5%

Overall Phosphorus Mass Balance

	Load		%Total	Conc.	
Precipitation Load	27.6	kg/yr	14%	37	ppb
Specified Load	19.6	kg/yr	10%	79	ppb
Internal Loading	146.0	kg/yr	76%	0	ppb
Point Load	0.0	kg/yr	0%	0	ppb
Total Load	193.1	kg/yr	100%	193	ppb
Sedimentation	185.6	kg/yr	96%		ppb
Outflow	7.6	kg/yr	4%	72	ppb

Model Information

Reservoir Volume (hm3):	1.932	Retention Coefficient:	0.961
Hydraulic Residence Time (yrs):	18.362	Reservoir P Conc (ppb):	72.0
Overflow Rate (m/yr):	0.10	Mass Residence Time (yrs):	0.0758
Inflow P Conc (ppb):	1836	Turnover Ratio:	13.2

Reductions

Needed Reduction (overland & internal loading): 32.3% 164.07 lbs/yr

Table 10. Lake modeling summary for Norway Lake (East Bay) (56-0569-01).

Lake Name:	Norway East		**WID:**	56-0569-01	
Eco-region:	NCHF		**Depth Class:**	Shallow	
<u>Models, Calibration Coefficients, and Predicted & Observed Values</u>					
Parameter	**Model**	**Calibration Coefficient**	**Observed**	**Predicted**	**Units**
Phosphorus	CB-LAKES	1.00	131.6	131.6	ppb
<u>Overall Water and Nutrient Balances</u>					
Overall Water Balance		Averaging Period =		1	years
	Flow	**Units**	**%Total**		
Precipitation Flow	0.85	hm3/yr	70.1%		
Specified Flow	0.36	hm3/yr	29.9%		
NonPoint Flow	0.00	hm3/yr	0.0%		
Point Flow	0.00	hm3/yr	0.0%		
Total Inflow	1.21	hm3/yr	100.0%		
Evaporation	1.10	hm3/yr	91.1%		
Outflow	0.04	hm3/yr	3.5%		
Overall Phosphorus Mass Balance					
	Load		**%Total**	**Conc.**	
Precipitation Load	33.2	kg/yr	5%	39	ppb
Specified Load	54.3	kg/yr	8%	150	ppb
Internal Loading	596.0	kg/yr	87%	0	ppb
Point Load	0.0	kg/yr	0%	0	ppb
Total Load	683.5	kg/yr	100%	565	ppb
Sedimentation	669.3	kg/yr	98%		ppb
Outflow	14.2	kg/yr	2%	337	ppb
<u>Model Information</u>					
Reservoir Volume (hm3):	2.324		Retention Coefficient:		0.979
Hydraulic Residence Time (yrs):	21.600		Reservoir P Conc (ppb):		131.6
Overflow Rate (m/yr):	0.085		Mass Residence Time (yrs):		0.0398
Inflow P Conc (ppb):	6353		Turnover Ratio:		25.1
<u>Reductions</u>					
Needed Reduction (overland & internal loading):		79.6%	1,196.12 lbs/yr		

Table 11. Lake modeling summary for Norway Lake (West Bay) (56-0569-02).

Lake Name:	Norway West		**WID:**	56-0569-02	
Eco-region:	NCHF		**Depth Class:**	Shallow	
<u>Models, Calibration Coefficients, and Predicted & Observed Values</u>					
Parameter	**Model**	**Calibration Coefficient**	**Observed**	**Predicted**	**Units**
Phosphorus	CB-LAKES	1.00	162.2	157.4	ppb
<u>Overall Water and Nutrient Balances</u>					
Overall Water Balance		Averaging Period =		1	years
	Flow	**Units**	**%Total**		
Precipitation Flow	0.25	hm3/yr	16.4%		
Specified Flow	1.18	hm3/yr	76.6%		
NonPoint Flow	0.00	hm3/yr	0.0%		
Advection	0.11	hm3/yr	7.0%		
Total Inflow	1.54	hm3/yr	100.0%		
Evaporation	0.33	hm3/yr	21.3%		
Outflow	1.21	hm3/yr	78.7%		
Overall Phosphorus Mass Balance					
	Load		**%Total**	**Conc.**	
Precipitation Load	9.8	kg/yr	2%	39	ppb
Specified Load	184.5	kg/yr	32%	157	ppb
Internal Loading	363.0	kg/yr	64%	0	ppb
Advection Load	14.2	kg/yr	2%	0	ppb
Total Load	571.5	kg/yr	100%	372	ppb
Sedimentation	381.2	kg/yr	67%		ppb
Outflow	190.3	kg/yr	33%	157	ppb
<u>Model Information</u>					
Reservoir Volume (hm3):	0.688		Retention Coefficient:		0.667
Hydraulic Residence Time (yrs):	0.569		Reservoir P Conc (ppb):		157.4
Overflow Rate (m/yr):	3.213		Mass Residence Time (yrs):		0.1492
Inflow P Conc (ppb):	473		Turnover Ratio:		6.7
<u>Reductions</u>					
Needed Reduction (overland & internal loading):		75.3%	956.88 lbs/yr		

Table 12. Lake modeling summary for Unnamed Lake (56-0791-00).

Lake Name:	Unnamed		**WID:**	56-0791-00	
Eco-region:	NCHF		**Depth Class:**	Shallow	

Models, Calibration Coefficients, and Predicted & Observed Values

Parameter	Model	Calibration Coefficient	Observed	Predicted	Units
Phosphorus	CB-LAKES	1.00	196.9	196.9	ppb

Overall Water and Nutrient Balances

Overall Water Balance		Averaging Period =		1	years
	Flow	**Units**	**%Total**		
Precipitation Flow	0.36	hm3/yr	51.6%		
Specified Flow	0.34	hm3/yr	48.4%		
NonPoint Flow	0.00	hm3/yr	0.0%		
Point Flow	0.00	hm3/yr	0.0%		
Total Inflow	0.71	hm3/yr	100.0%		
Evaporation	0.49	hm3/yr	69.8%		
Outflow	0.21	hm3/yr	30.2%		
Overall Phosphorus Mass Balance					
	Load		**%Total**	**Conc.**	
Precipitation Load	14.8	kg/yr	3%	41	ppb
Specified Load	103.2	kg/yr	21%	303	ppb
Internal Loading	367.0	kg/yr	76%	0	ppb
Point Load	0.0	kg/yr	0%	0	ppb
Total Load	485.0	kg/yr	100%	687	ppb
Sedimentation	443.0	kg/yr	91%		ppb
Outflow	41.9	kg/yr	9%	197	ppb

Model Information

Reservoir Volume (hm3):	0.690	Retention Coefficient:	0.914
Hydraulic Residence Time (yrs):	3.239	Reservoir P Conc (ppb):	196.9
Overflow Rate (m/yr):	0.38	Mass Residence Time (yrs):	0.0846
Inflow P Conc (ppb):	2277	Turnover Ratio:	11.8

Reductions

Needed Reduction (overland & internal loading):	88.8%	942.83 lbs/yr

Table 13. Lake modeling summary for Devils Lake (56-0882-00).

Lake Name:	Devils		**WID:**	56-0882-00	
Eco-region:	NCHF		**Depth Class:**	Shallow	

<u>Models, Calibration Coefficients, and Predicted & Observed Values</u>

Parameter	Model	Calibration Coefficient	Observed	Predicted	Units
Phosphorus	CB-LAKES	1.00	100.4	100.3	ppb

<u>Overall Water and Nutrient Balances</u>

Overall Water Balance		Averaging Period =		1	years
	Flow	**Units**	**%Total**		
Precipitation Flow	0.87	hm3/yr	47.9%		
Specified Flow	0.94	hm3/yr	52.1%		
NonPoint Flow	0.00	hm3/yr	0.0%		
Point Flow	0.00	hm3/yr	0.0%		
Total Inflow	1.81	hm3/yr	100.0%		
Evaporation	1.06	hm3/yr	58.5%		
Outflow	0.75	hm3/yr	41.5%		
Overall Phosphorus Mass Balance					
	Load		**%Total**	**Conc.**	
Precipitation Load	32.5	kg/yr	6%	38	ppb
Specified Load	125.2	kg/yr	24%	133	ppb
Internal Loading	363.0	kg/yr	70%	0	ppb
Point Load	0.0	kg/yr	0%	0	ppb
Total Load	520.8	kg/yr	100%	288	ppb
Sedimentation	445.6	kg/yr	86%		ppb
Outflow	75.2	kg/yr	14%	100	ppb

<u>Model Information</u>

Reservoir Volume (hm3):	2.280	Retention Coefficient:	0.856
Hydraulic Residence Time (yrs):	3.039	Reservoir P Conc (ppb):	100.3
Overflow Rate (m/yr):	0.60	Mass Residence Time (yrs):	0.1820
Inflow P Conc (ppb):	694	Turnover Ratio:	5.5

<u>Reductions</u>

Needed Reduction (overland & internal loading): 60.1% 722.08 lbs/yr

Table 14. Lake modeling summary for Grandrud Lake (56-0907-00).

Lake Name:	Grandrud		**WID:**	56-0907-00	
Eco-region:	NCHF		**Depth Class:**	Shallow	
Models, Calibration Coefficients, and Predicted & Observed Values					
Parameter	**Model**	**Calibration Coefficient**	**Observed**	**Predicted**	**Units**
Phosphorus	CB-LAKES	1.00	61.5	61.5	ppb
Overall Water and Nutrient Balances					
Overall Water Balance		Averaging Period =		1	years
	Flow	**Units**	**%Total**		
Precipitation Flow	0.32	hm3/yr	49.1%		
Specified Flow	0.33	hm3/yr	50.9%		
NonPoint Flow	0.00	hm3/yr	0.0%		
Point Flow	0.00	hm3/yr	0.0%		
Total Inflow	0.65	hm3/yr	100.0%		
Evaporation	0.39	hm3/yr	60.1%		
Outflow	0.26	hm3/yr	39.9%		
Overall Phosphorus Mass Balance					
	Load		**%Total**	**Conc.**	
Precipitation Load	12.0	kg/yr	13%	38	ppb
Specified Load	30.7	kg/yr	32%	93	ppb
Internal Loading	52.5	kg/yr	55%	0	ppb
Point Load	0.0	kg/yr	0%	0	ppb
Total Load	95.2	kg/yr	100%	147	ppb
Sedimentation	79.3	kg/yr	83%		ppb
Outflow	15.9	kg/yr	17%	62	ppb
Model Information					
Reservoir Volume (hm3):	0.977		Retention Coefficient:		0.833
Hydraulic Residence Time (yrs):	3.780		Reservoir P Conc (ppb):		61.5
Overflow Rate (m/yr):	0.56		Mass Residence Time (yrs):		0.2520
Inflow P Conc (ppb):	368		Turnover Ratio:		4.0
Reductions					
Needed Reduction (overland & internal loading):		4.5%	38.49 lbs/yr		

Table 15. Lake modeling summary for Johnson Lake (56-0979-00).

Lake Name:	Johnson		**WID:**	56-0979-00	
Eco-region:	NCHF		**Depth Class:**	Shallow	

Models, Calibration Coefficients, and Predicted & Observed Values

Parameter	Model	Calibration Coefficient	Observed	Predicted	Units
Phosphorus	CB-LAKES	1.06	97.7	97.7	ppb

Overall Water and Nutrient Balances

Overall Water Balance Averaging Period = 1 years

	Flow	Units	%Total
Precipitation Flow	0.42	hm3/yr	38.7%
Specified Flow	0.66	hm3/yr	61.3%
NonPoint Flow	0.00	hm3/yr	0.0%
Point Flow	0.00	hm3/yr	0.0%
Total Inflow	1.08	hm3/yr	100.0%
Evaporation	0.54	hm3/yr	50.3%
Outflow	0.53	hm3/yr	49.7%

Overall Phosphorus Mass Balance

	Load		%Total	Conc.	
Precipitation Load	16.3	kg/yr	11%	39	ppb
Specified Load	134.9	kg/yr	89%	205	ppb
Internal Loading	0.0	kg/yr	0%	0	ppb
Point Load	0.0	kg/yr	0%	0	ppb
Total Load	151.1	kg/yr	100%	141	ppb
Sedimentation	98.9	kg/yr	65%		ppb
Outflow	52.3	kg/yr	35%	98	ppb

Model Information

Reservoir Volume (hm3):	0.380	Retention Coefficient:	0.654
Hydraulic Residence Time (yrs):	0.710	Reservoir P Conc (ppb):	97.7
Overflow Rate (m/yr):	0.86	Mass Residence Time (yrs):	0.1221
Inflow P Conc (ppb):	283	Turnover Ratio:	8.2

Reductions

Needed Reduction (overland & internal loading): 55.5% 181.85 lbs/yr

Table 16. Lake modeling summary for Oscar Lake (56-0982-00).

Lake Name:	Oscar		**WID:**	56-0982-00	
Eco-region:	NCHF		**Depth Class:**	Shallow	
<u>Models, Calibration Coefficients, and Predicted & Observed Values</u>					
Parameter	**Model**	**Calibration Coefficient**	**Observed**	**Predicted**	**Units**
Phosphorus	CB-LAKES	1.00	151.4	151.4	ppb
<u>Overall Water and Nutrient Balances</u>					
Overall Water Balance		Averaging Period =		1	years
	Flow	**Units**	**%Total**		
Precipitation Flow	0.91	hm3/yr	14.4%		
Specified Flow	5.39	hm3/yr	85.6%		
NonPoint Flow	0.00	hm3/yr	0.0%		
Point Flow	0.00	hm3/yr	0.0%		
Total Inflow	6.30	hm3/yr	100.0%		
Evaporation	1.18	hm3/yr	18.8%		
Outflow	5.12	hm3/yr	81.2%		
Overall Phosphorus Mass Balance					
	Load		**%Total**	**Conc.**	
Precipitation Load	35.6	kg/yr	2%	39	ppb
Specified Load	946.3	kg/yr	60%	176	ppb
Internal Loading	600.0	kg/yr	38%	0	ppb
Point Load	0.0	kg/yr	0%	0	ppb
Total Load	1581.8	kg/yr	100%	251	ppb
Sedimentation	806.8	kg/yr	51%		ppb
Outflow	775.0	kg/yr	49%	151	ppb
<u>Model Information</u>					
Reservoir Volume (hm3):	1.246		Retention Coefficient:		0.510
Hydraulic Residence Time (yrs):	0.244		Reservoir P Conc (ppb):		151.4
Overflow Rate (m/yr):	3.76		Mass Residence Time (yrs):		0.0969
Inflow P Conc (ppb):	309		Turnover Ratio:		10.3
<u>Reductions</u>					
Needed Reduction (overland & internal loading):		70.3%	2,560.12 lbs/yr		

Table 17. Lake modeling summary for Holvand Lake (56-1014-00).

Lake Name:	Hovland		**WID:**	56-1014-00	
Eco-region:	NCHF		**Depth Class:**	Shallow	
Models, Calibration Coefficients, and Predicted & Observed Values					
Parameter	**Model**	**Calibration Coefficient**	**Observed**	**Predicted**	**Units**
Phosphorus	CB-LAKES	1.00	185.0	185.0	ppb
Overall Water and Nutrient Balances					
Overall Water Balance		Averaging Period =		1	years
	Flow	**Units**	**%Total**		
Precipitation Flow	0.51	hm3/yr	29.7%		
Specified Flow	1.21	hm3/yr	70.3%		
NonPoint Flow	0.00	hm3/yr	0.0%		
Point Flow	0.00	hm3/yr	0.0%		
Total Inflow	1.71	hm3/yr	100.0%		
Evaporation	0.62	hm3/yr	36.3%		
Outflow	1.09	hm3/yr	63.7%		
Overall Phosphorus Mass Balance					
	Load		**%Total**	**Conc.**	
Precipitation Load	19.1	kg/yr	2%	38	ppb
Specified Load	225.3	kg/yr	19%	187	ppb
Internal Loading	929.0	kg/yr	79%	0	ppb
Point Load	0.0	kg/yr	0%	0	ppb
Total Load	1173.4	kg/yr	100%	684	ppb
Sedimentation	971.2	kg/yr	83%		ppb
Outflow	202.1	kg/yr	17%	185	ppb
Model Information					
Reservoir Volume (hm3):	1.562		Retention Coefficient:		0.828
Hydraulic Residence Time (yrs):	1.429		Reservoir P Conc (ppb):		185.0
Overflow Rate (m/yr):	1.49		Mass Residence Time (yrs):		0.1569
Inflow P Conc (ppb):	1074		Turnover Ratio:		6.4
Reductions					
Needed Reduction (overland & internal loading):		83.6%	2,196.32 lbs/yr		

Table 18. Lake modeling summary for Twin Lake (56-1525-00).

Lake Name:	Twin		**WID:**	56-1525-00	
Eco-region:	NCHF		**Depth Class:**	Shallow	
<u>Models, Calibration Coefficients, and Predicted & Observed Values</u>					
Parameter	**Model**	**Calibration Coefficient**	**Observed**	**Predicted**	**Units**
Phosphorus	CB-LAKES	1.00	140.4	140.4	ppb
<u>Overall Water and Nutrient Balances</u>					
Overall Water Balance		Averaging Period =		1	years
	Flow	**Units**	**%Total**		
Precipitation Flow	0.51	hm3/yr	53.4%		
Specified Flow	0.44	hm3/yr	46.6%		
NonPoint Flow	0.00	hm3/yr	0.0%		
Point Flow	0.00	hm3/yr	0.0%		
Total Inflow	0.95	hm3/yr	100.0%		
Evaporation	0.62	hm3/yr	65.2%		
Outflow	0.33	hm3/yr	34.8%		
Overall Phosphorus Mass Balance					
	Load		**%Total**	**Conc.**	
Precipitation Load	19.1	kg/yr	5%	38	ppb
Specified Load	71.0	kg/yr	19%	160	ppb
Internal Loading	275.5	kg/yr	75%	0	ppb
Point Load	0.0	kg/yr	0%	0	ppb
Total Load	365.6	kg/yr	100%	384	ppb
Sedimentation	319.1	kg/yr	87%		ppb
Outflow	46.5	kg/yr	13%	140	ppb
<u>Model Information</u>					
Reservoir Volume (hm3):	0.892		Retention Coefficient:		0.873
Hydraulic Residence Time (yrs):	2.694		Reservoir P Conc (ppb):		140.4
Overflow Rate (m/yr):	0.45		Mass Residence Time (yrs):		0.1191
Inflow P Conc (ppb):	1104		Turnover Ratio:		8.4
<u>Reductions</u>					
Needed Reduction (overland & internal loading):		78.8%	632.51 lbs/yr		